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U. S. DEPARTMENT OF AGRICULTURE

STORAGE OF PEA BEANS in Michigan and Indiana

U. S. DEPARTMENT OF AGRICULTURE
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PREFACE

The initial phase of this study was undertaken at the request of the Commodity Credit Corporation when large quantities of pea beans were taken over by that agency for storage under the Government price-support program for dry edible beans - effective with the 1949 crop. At that time, very little information was available on storage of beans as it had been the policy of the trade to move the entire pea bean stocks each marketing season to canners, brokers, packagers, and destination distributors, carrying very little, if any, of the old crop beyond the harvest of the new beans.

The storage of Government-owned beans in bulk in large silo tanks was a new procedure. Therefore, a research project was initiated to determine changes in the quality of pea beans when stored in bulk in silo-type tanks and during handling to determine the effect of aeration in maintaining the quality of pea beans during the storage period.

In addition to the storage research carried on at Ash Grove, Ind., and Caro, Mich., testing aeration techniques and methods of stacking to more efficiently maintain the quality of pea beans stored at CCC bin sites, work was initiated in cooperation with Michigan State University to determine from a pilot study temperature and humidity ranges suitable for the storage of dry beans of varying moisture contents; to classify the kinds of mold found in beans; and to determine the conditions under which harmful mold strains are most active.

The scope of the storage study covered a number of different problems requiring the assistance of a number of qualified technicians. Therefore, the authors wish to acknowledge the outstanding help and assistance from the following: George H. Foster, agricultural engineer, Agricultural Marketing Service, USDA, stationed at Purdue University, directed the study at Ash Grove, Ind., and Caro, Mich., and performed aeration experiments to maintain quality of beans; C. W. Hall, professor in agricultural engineering, Michigan State University, headed the Michigan warehouse temperature and humidity study to control molds and deterioration; Herman F. Mayes, agricultural engineer of AMS, located at Purdue University, assisted Mr. Foster. Special credit is also given Dr. S. T. Dexter, professor of farm crops, and Dr. A. L. Andersen, plant pathologist, Horticulture Crops Research Branch, ARS, and Department of Botany and Plant Pathology, Michigan State University, on their work pertaining to storage response of white pea beans to various humidities and temperatures. Leo Holman and W. C. Dachtler of AMS, assisted with the planning of this work and gave helpful guidance to the research at all times.

In the trade, considerable help was received from the Michigan Bean Shippers Association and its secretary, Maurice A. Doan.

The following firms, all of whom are located in Michigan, cooperated by permitting their elevators and warehouses to be used in the research work: Michigan Elevator Exchange, Wallace and Morley Company, Breckenridge Bean and Grain Company, Ithaca Roller Mills, Charles Wolohan, Inc., and Frutchey Bean Company.

Special appreciation is also due to members of the Dry Beans and Peas Research and Marketing Advisory Committee who were so helpful in guiding this research.

The Michigan State ASC Office and the Tuscola County Office, Caro, Mich., the Indiana State ASC Office, and the Tippecanoe County Office, LaFayette, Ind. were especially cooperative and helpful.

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STORAGE OF PEA BEANS
in
Michigan and Indiana

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Summary

The study of pea bean storage was made to determine what factors are most important for maintaining quality, preventing the formation of harmful molds and discoloration, and controlling insects in beans which are to be held in storage for a period longer than one marketing year. A comparison was made of different methods of bag and bulk storage in various types of warehouses, bulk houses, quonsets, and other bins using both natural and mechanical aeration. These tests were carried out under controlled conditions in the laboratory and under actual commercial practices. Consideration was given to the various combinations of temperatures and humidity conditions that would result in the most desirable moisture content for stored beans.

Findings of this study indicate that:

1. Storage of pea beans beyond the first year in high-humidity areas such as Michigan and Indiana must be managed with extreme care because the resistance of dry bean seedcoats to mold and bacterial growth apparently diminishes rapidly after about one year.

2. The most desirable warehouse storage conditions are obtained when a combination of temperature and humidity results in a moisture equilibrium in the beans of 17 percent or less.

3. The moisture content of relatively dry beans (14 to 16 percent) may slowly reach equilibrium at about 17 percent under constant storage conditions of about 76 percent of relative humidity (RH) and 50° F. At the higher temperatures and humidities, discoloration and mustiness are more likely to occur; for example, beans with 17-percent moisture will keep better at 60° F. than at 85°.

4. In general, warehousemen have considered beans with 16-percent moisture as being safe for storage under average temperature or humidity conditions. However, discoloration may occur in beans with 16-percent moisture if temperatures reach 80° F. or higher for several weeks when the humidity is high.

1/ Project leader and coordinator of research, Washington, D. C.
2/ Local representative responsible for accumulation of storage data, Michigan State University, East Lansing, Michigan.

5. During the first year (September through August) beans may be stored at 17- to 18-percent moisture content, but mold is likely to develop on beans stored the second year if the moisture is 16½ percent or above.

6. In warehouse storage of bagged beans, the use of pallets on the first and second tiers does not keep down moisture or fat acidity. The use of pallets cannot be considered economically advantageous, except as an aid to handling.

7. Piling bags on edge (as shown on the cover page) has several advantages over stacking bags in the normal manner: (a) It is possible to obtain a more uniform application of fumigants, and (b) the extended base of the bags locks the adjacent tiers together so that a more sturdy pile results.

8. Chimney stacking of bagged beans (with a 30-inch square space in the center of the pile) resulted in a more rapid moisture change of beans in the entire pile after several months of storage, when atmospheric conditions in the storage are suitable for drying.

9. Bulk storage is found to be practical if certain precautions are taken; namely, (a) leveling off the top of the bin when the beans are first stored to avoid a rise of moisture to the highest area; (b) distributing thermocouples throughout the bin so that any "hot spots" may be detected; (c) elevating the beans to another bin, thereby cooling and breaking up the trouble area; or (d) cooling with forced aeration by circulating cold air through the bin of bulk beans.

10. When warehouses are cool inside, they should not be opened except for short periods when outside temperatures and humidities are high, as when a temperature difference of 25° F. or more exists, condensation of moisture will appear on the exposed beans near the outside of the pile in significant quantities. This in turn results in a higher humidity in the warehouse and a subsequent increase in the moisture content of all beans in the storage.

11. Fat acidity cannot be considered a very satisfactory quality-evaluating factor. However, until a better factor has been determined, it will act as a rough gage to alert the warehouseman to danger of quality deterioration. In these studies, fat acidity analyses were made as a quality-evaluation factor, to see if this value could be used as a guide to determine when beans should be moved or marketed before they were about to go out of condition. Dry beans usually have a fat acidity value of 30-40 before any noticeable breakdown can be detected. Samples with a fat acidity of 40 or above should be considered unfit for storage and should be marketed promptly.

12. Indian-meal moth may be controlled by (a) pyrethrum sprays on bulk beans, (b) pyrethrum aerosols on bag beans, or (c) fumigation with 80-20 (80-percent carbon tetrachloride and 20-percent carbon disulphide), or (d) by chloropicrin in bag storage.

BACKGROUND

Under the Government price-support program for dry edible beans, which became effective with the 1949 crop, large quantities of pea beans (navy) were taken over by the Commodity Credit Corporation for storage. Not enough suitable storage was available in Michigan so substantial quantities of dry beans were moved into Ohio and other areas, with little idea as to when the beans would be sold or moved out. A number of empty sugar warehouses and similar storage buildings in the Toledo-Detroit area were approved by CCC for storage purposes.

The 1948 and 1949 pea bean crops totaled nearly 10 million 100-pound bags, slightly larger than the 9.6-million bag total for the three years 1945, 1946, and 1947. The CCC took over 640,000 bags of pea beans from the 1948 crop and, because of the very large pea bean crop of 5,334,000 bags in 1949, was under obligation to take over 1,845,000 additional bags (Table 1). With pea beans worth about $8 per cwt., their storage had important economic implications.

Table 1.--Production of dry edible beans and estimated quantities acquired by Commodity Credit Corporation 1944-55, 1/

Year	Pea beans		All beans	
	Production 2/	Government-acquired 3/	Production 2/	Government-acquired 3/
	(Thousand 100-lb. bags - cleaned basis)			
1944	4,422	-	15,044	-
1945	2,687	-	11,950	-
1946	3,814	-	14,702	-
1947	3,074	-	15,829	-
1948	4,476	640	19,384	5,100
1949	5,334	1,845	19,863	6,100
1950	3,356	10	15,155	780
1951	4,072	1,130	15,879	1,830
1952	3,412	235	15,010	790
1953	3,607	257	16,818	1,648
1954	3,185	-	17,063	2,900
1955	4,622	4/700	17,287	4/1,800

1/ The acquisition data for "pea beans" are not based on official records. The data for "all beans" represent forfeiture of loan collateral and quantities delivered under purchase agreements and, as such, are subject to minor adjustments to determine the actual amount acquired.
2/ Crop Reporting Board.
3/ In May 1949, CCC acquired substantial quantities of 1948 crop beans under a price-support program. Estimated quantities for the 1948 and subsequent crops are shown.
4/ Estimated takeover from 1955 crop.

Very little information on storage of beans was available as it has been the policy of the trade to move the entire pea bean stocks each marketing season to canners, brokers, packagers, and destination distributors, carrying very little, if any, of the old crop beyond the harvest of the new beans.

Bulk Storage Compared with Bag Storage

One phase of the storage study was to determine if dry beans could be stored satisfactorily in bulk (similar to grain storage) and, if so, how much aeration and maintenance care is required. Storage in bags has been the usual practice in most of the producing areas. It was found, however, with some of the first pea beans taken over by CCC, that damage usually occurred near the center of the pile and more generally in the first, second, and third tiers of bags. Suggestions were made for the initiation of research to determine if it might be possible to place pallets (to permit two or more inches of air space) between tiers and alleviate this trouble. Also, turning bags on edge to increase the internal air space had been suggested.

Mold Problems

A few lots of the 2-year old beans, when sold to canners, contained internal mold. When the beans were presoaked and the seedcoat became translucent, the floating bodies of black mold spores could be observed between the seedcoat and the cotyledon. The free water in this area was sufficient to float the mold spores from one side of the bean to the other and was actually quite a problem to the industry. The beans with the hidden mold could not be removed with the electric-eye sorting machine as the spots were not detectable in the dry beans. In addition to the anaerobic types of mold there are several types of surface mold that will develop on the hilum or in cracks of the dry bean when different variations of temperature and humidity occur. Therefore, studies to cover these problems were included.

It has been normal for growers and country shippers in Michigan and New York to harvest and handle beans with 18- or 19-percent moisture without drying as they are normally sold before summer or warm weather. These bagged beans, when kept cool in a good storage, ordinarily present no problems for the first few months. Shippers carefully observe extra-high-moisture beans and sell them to canners or ship them to wholesalers or distributors who do not store them for any extended time. The seedcoat of the new bean has a protective coating which is resistant to mold and deterioration for several months, but when beans are stored the second winter it becomes necessary to take precautionary measures that were not previously needed.

Although many of the beans taken over by CCC contained only 16- or 17-percent moisture, they were over 1-year old; it was found that beans cannot safely carry as much water after the first year. Mold may develop in the older beans if the storage humidity is sufficiently high for the moisture content of the beans to rise to 16.5 percent before equilibrium with the air is reached.

Type of Storage Structure Used

Lack of regular dry bean storage space made it necessary for CCC to approve steel bins and quonsets as well as silo-type structures to hold the beans being taken over. Little was known about methods of aerating and handling the beans in the different buildings to avoid serious losses through splits and breakage and through damage from mustiness and mold.

Moisture Change at Controlled Humidity

Some research had been done regarding equilibrium moisture with storage humidities and temperatures. At the Western Regional Research Laboratory, Michelite beans were stored in different relative humidities of 10, 20, 30, 40, 50, 60, 70, 80, 90, 94, 96, 98, and 100 percent, at room temperature (77° F.). Fifty grams of about 14-percent moisture beans were used." The rate of moisture content change was proportional to the relative humidity at the value of 70 percent and above. At values of 60 percent and below, the rate of change initially was inversely proportional to the humidities."3/ It was found that storing Michelite beans at 80-percent relative humidity for 136 days caused an increase in moisture to about 20 percent which was sufficient to support mold growth.

Mold occurred when beans held at 90 percent relative humidity had a moisture content of 22 percent; at 94-to 98-percent relative humidity about 23 percent; and at 100-percent relative humidity, about 24-percent moisture. The time in which mold developed ranged from 32 days in the 100-percent relative humidity storage to 59 days at 98 percent RH, 66 days at 96 RH, and 80 days at 90 and 94 percent RH.

SCOPE AND LOCATION OF STUDIES

It was considered advisable to study several regular storage warehouses in the bean-producing area of Michigan and keep accurate temperature and humidity records for each structure for comparison with results obtained under controlled conditions in California and at Michigan State University. Therefore, since so many beans were involved, and because substantial depreciation of the commodity was likely in the absence of proper precautions and care, research was instituted for study of the most economical methods of storing dry beans beyond the normal period when the humidity may cause the moisture to rise in the beans to a point where deterioration sets in.

CCC-owed beans were stored under contract in large bulk silos at Marysville, Mich.--a new experience for both the trade and CCC.

3/ Processing Quality of Varieties and Strains of Dry Beans, by H. J. Morris, R. L. Olson and R. C. Bean, Western Regional Research Laboratory, Albany, Calif., Food Technology 1950, Vol. 4, No. 6.

Since bag storage had been unsatisfactory in some warehouses, CCC welcomed an opportunity to enter into a bulk storage contract to test the possibility of utilizing commercial grain storage elevator and steel bin space not suitable for bag storage. Bulk storage had been used by the industry for a limited period at the beginning of the season but not for longtime storage. In accordance with recommendations of Federal engineers, the contractor equipped the tanks with floor ducts and exhaust fans, and installed sufficient thermocouples and temperature-recording systems to be able to quickly locate the development of heating areas.

Arrangements were made to make temperature readings and to sample the bulk beans at Marysville, Mich., for moisture and fat acidity analyses.

Because of the urgent need for storage research information, the Michigan dry bean trade gave its support to high priority for this work on dry bean storage research. The Michigan Bean Shippers Association entered into an agreement with Michigan State University, in which each organization contributed funds for the dry bean research over a 2-year period.

Six warehouses owned and operated by the trade (Appendix, figs. 23-28) were used in the study. The owners and managers of these plants cooperated with Michigan State University to complete a study of bean warehouse facilities and storage conditions.

Laboratory Studies

Laboratory studies of white pea beans were initiated at Michigan State University by storing different samples of beans at several different temperatures and relative humidities. The beans were kept in closed containers, with saturated salt solutions to control humidity. Analyses were made each month for moisture, fat acidity, and mold growth. The first data were taken in February 1953 and the last in January 1954.

Warehouse Studies

Warehouse studies were made in Michigan to obtain information about (a) actual storage conditions, (b) the change in quality of the beans in these warehouses, (c) the relationship of storage conditions to change in bean quality, and (d) the relationship of storage conditions to weather conditions. Six different types of commercial bean storage warehouses were selected in the principal bean-growing area in Michigan (Appendix, figs. 23-28). Continuous temperature and humidity records were made of the storage conditions inside these warehouses. Samples of the beans in storage were removed monthly for analyses to determine the change in the beans. They were tested for moisture, fat acidity, and mold growth. Weather data were obtained from nearby U. S. weather stations for comparison with inside storage conditions.

Ventilation Studies

Seven carloads of bagged Michigan pea beans were delivered to Ash Grove, Ind., in February 1953, for storage tests in quonset-type grain

Table 2.--Treatments and sample identification for tests at Ash Grove, Ind.

Stack no.	Treatment	Sample no.	Notes
I-A	Bags flat, no pallets	1-AR)	R - represents a sample drawn from the bottom three tiers of bags.
I-B	Bags flat, pallets 1st tier	1-BR)1-T	
I-C	Bags flat, pallets 2nd tier	1-CR)	
II-A	Bags edged, no pallets	2-AR)	T - in stacks I and II, represents a composite sample made up from all sampling points above the bottom three tiers in the designated piles.
II-B	Bags edged, pallets 1st tier	2-BR)2-T	
III-C	Bags edged, pallets 2nd tier	2-CR)	
III-A	Bags flat, square chimney located in center of stack	3-AR 3-A	
III-B	Bags edged, square chimney located in center of stack.	3-BR 3-B	
III-C	Bags edged, square chimney located in center of stack and pallets on 2nd tier.	3-CR 3-C	SH & L - denotes samples drawn from short and long tubes, respectively.
III-D	Bags flat, square chimney located in center of stack. Large stack	3-DRSH 3-DSH 3-DRL 3-DL	Short tubes are 30 inches in length and long tubes are 60 inches in length.
III-E	Bags flat in two sections with 6-inch open space between.	3-E	
IV	Carload stack, ½HP 20" fan forces air through vertical duct.	4-SH 4-L	
V	Carload stack, ½HP 20" fan draws air through vertical duct.	5-SH 5-L	
VI	Carload stack, 1/20HP 8" fan draws air through vertical duct.	6-SH 6-L	
VII	Carload stack, ½HP 20" fan, draws air through horizontal tunnel.	7-M 7-N	In stack VII, 7-M denotes sample from bottom four tiers and 7-N a sample from all sampling points above the fourth tier.

storage buildings to determine (1) storage temperatures and relative humidity ranges, (2) aerating techniques and equipment, and (3) methods of stacking bags more effectively to maintain the quality of pea beans stored at CCC bin sites. Different stacking arrangements were used to study the effects of mechanical ventilation equipment and the effect of increasing the amounts of natural air movement through the beans by use of pallets. (See table 2).

Three carloads of beans were delivered to Caro, Mich., in February and April 1953. These beans were stored in four, round, metal bins. One carload was stored in each of two bins. The other carload was stored in the sack and divided between the remaining two bins.

In July 1952, a project was initiated in cooperation with the Michigan Elevator Exchange, Lansing, Mich. to determine (1) changes in the quality of pea beans stored in silo-type tanks and (2) the effectiveness of aeration. Forty cars of bulk pea beans were stored for CCC in two bins 32 feet in diameter by 60 feet high at Marysville, Mich.

Insect Control

On August 29 and September 12, 1952, the two silo tanks of bulk beans at Marysville, Mich., were treated for Indian-meal moth by the Stored-Product Insect Section, AMS. Also, additional insect-control experiments on CCC-stored beans in bags were performed at Toledo, Ohio, and Ash Grove, Ind.

Controlled Relative Humidity and Mold Development

Samples of dry beans were stored under controlled relative humidity and temperature at Michigan State University. Mold populations were determined periodically, and observations were made on discoloration and rancidity.

METHODOLOGY AND TEST RESULTS

Laboratory Studies

Procedure:--Michelite beans from the 1951 and the 1952 Michigan bean crops were selected for storage. The 1951 crop was damp and discolored when harvested because of poor harvesting conditions. The 1952 beans were choice, hand-picked beans of good quality.

Beans of these two crops were stored at 60° and 85° F., at controlled relative humidities of 52, 75, and 90 percent. At 40° F., they were stored at controlled humidities of 52 and 90 percent; at 100° F., at controlled humidities of 52 percent.

The desired humidities were maintained by saturated salt solutions. Quart samples of the 1952 crop and pint samples of the 1951 crop were stored in closed drums containing the exposed saturated salt solution.

A portion of the lot of 1951 beans used in these tests was stored in bags at 0° F. These are designated in the report as "1951 crop, 0° F."

A lot of wet 1952 beans was obtained and stored in bags in a 40° F. walk-in-type cooler in November 1952. This cooler had continuous air circulation and maintained a relative humidity of from 80 to 85 percent. This lot has been designated as "1952 crop, lot A, 40° F. cooler." A portion of this 1952 crop, lot A, stored at 40° F., was moved to a 0° F. storage in February 1953. This lot is designated as "1952 crop, lot A, 0° F."

Samples of the beans under test were removed from storage once each month for analyses and observation. A portion of each was sent to a USDA Research Center at either Peoria, Ill., or Beltsville, Md., for moisture and fat acidity analyses. Mold counts were made on the remaining portions by the Department of Botany and Plant Pathology, Michigan State University.

The method used in making mold counts was to select 50 gms. of beans from the samples and wash in 25 cc. of water to remove spores of molds. Several suitable dilutions were made of this spore suspension and plated on malt-salt-agar. Counts of mold colonies were made after five days, and are expressed in colonies per gram of beans. The analyses of these experimental beans are shown in (Appendix, figs. 29-32 and table 4).

Discussion:--At 52-percent RH, beans held at 85°, 60° and 40° F. did not indicate deterioration, maintaining low mold counts and normal fat acidity values. The moisture content, however, was lower than desirable and after eight months of storage remained in the range of 11-to 12-percent moisture at 85° F., and 12 to 13 percent at 60° F., and 10 to 13 percent at 40° F.

At 75-percent RH, the beans stored at 85° F. deteriorated progressively, accompanied by increasing fat acidity values and also by increasing mold counts in the case of the 1951 (poor quality) beans. At 60° F. the beans kept longer than at 85°, with more acceptable moisture (16- to 18-percent) range and fat acidity values. Here again, the mold count values in the 1951 beans increased as the beans deteriorated, while those of the 1952 (good quality) crop, remained low throughout the 12-month storage period. No comparable beans were stored at 40° F. and 75-percent RH. However, a lot of beans of initially high moisture and poor quality (1952 crop, lot A) was stored in burlap bags in the 40° F. cooler which varied in RH in the 80 to 85 percent range. These continued to deteriorate with increasingly high moisture content and mold counts though fat acidity readings decreased.

At 90-percent RH, all beans stored at 40°, 60°, and 85° F. deteriorated quite rapidly, accompanied by a progressively increasing moisture content. Fat acidity increased at 85° F. but held constant at the other temperatures. Mold counts increased as the beans deteriorated, except in the case of the 1952 crop, stored at 40° F. The 1951 crop was of poor quality and mold counts were much higher than on the 1952 crop.

Conclusions:--The 1951 crop of beans, which were of poor quality initially, exhibited a greater tendency to deteriorate than the 1952 beans of good quality. Of the storage conditions tested, the 60° F. 75-percent RH conditions maintained a desirable moisture content in the good quality beans without rapid spoilage. Zero degree F. storage maintained initial bean quality more effectively than at the warmer temperatures tested. Fat acidity increased as the beans deteriorated at 85° F., but not at the other temperatures studied.

Recommendations:--These laboratory studies indicate that beans that are initially of good quality will store better than those of poor quality. Therefore, it is suggested that beans of poor quality be moved first.

Other things being equal, the cooler the beans are kept, the better they will store. During the winter when the temperature is low, it would be helpful to thoroughly cool the beans as well as the unoccupied warehouse air space. During the summer every effort should be made to avoid opening doors and windows more than necessary until the beans are marketed. It should be remembered that moisture may condense on cool beans if exposed to warm humid air and burlap bags may become quite moist. Such moisture on the surface of beans offers excellent conditions for the growth of mold and should be avoided. If possible, the beans should not be exposed to extreme sudden changes in temperature to avoid such condensation.

Warehouse Studies

Six commercial bean warehouses of different types of construction were chosen as follows:

Warehouse A.--This is a wooden-floored, metal-clad building adjoining an elevator. The roof is well-insulated, and the east, west and south walls partially insulated. A picture and sketch are shown in the Appendix, fig. 23. About two-thirds of the available floor area is used for bean storage, with the remaining space as a work area for general elevator operation. The storage area is open frequently to outside weather conditions. Normally, there are about four or five carloads of bagged beans stored in this warehouse. The test beans were from the 1952 crop, Michelite variety, produced in that area.

Warehouse B.--This is a newly constructed warehouse. The walls are constructed of 8-inch "Celocrete" (cinder-like) insulation blocks to the plate, with uninsulated galvanized metal siding and roofing above. A sketch and picture of the warehouse are shown in the Appendix, fig. 24. The floor is concrete, doors are insulated, no windows and no ventilation are provided. During the spring and early summer the warehouse was required as a general work area and the doors remained open much of the time during the working day.

The warehouse capacity is about 10 to 12 carloads of beans. The test beans were 1952 Michelite beans grown in the surrounding area.

The storage conditions in these warehouses were continuously recorded by hygrothermographs of the hair-element type located beside the test lots. Figures 35-42 show these data in graphic form. Outside weather conditions, as taken from the U. S. Weather Bureau records, are also shown for comparison.

Quality studies of the beans throughout some of the carload test lots were made at the time the beans were moved. Details of the lots tested, together with the location of the samples taken and the resulting analyses, are shown in figures 43-45.

Discussion:--In all warehouses with concrete floors, the beans were stacked on wooden racks to hold the beans about 2 inches above the floor. All carload lots were separated from each other and from walls by 1 to 2 feet. Typical lots are from 10 to 12 feet in height, 8 to 10 feet in width, and from 16 to 18 feet in length. Some of the lots were moved out during the test period. However, a bag was saved from the edge of each of these lots where samples were normally taken and kept in the warehouse for continued storage and sampling.

The management practices in these warehouses varied considerably, depending on the understanding of the warehousemen of desirable storage conditions and the necessity for using the warehouses for purposes other than the storage of beans.

It is difficult to classify these warehouses, except to point out the extreme differences of warehouses D and E (Bay City No. 15 and Carrollton) from A and B (Bradleyville and Breckenridge) warehouses. The former are large storages, closed directly to outside weather conditions most of the time, while the latter are open much of the time in the spring and summer because of other uses for the warehouses. On this basis, the former warehouse D (Bay City No. 15) and warehouse E (Carrollton) exhibited less daily dry bulb temperature variation (Appendix fig. 41 and 42) and less relative humidity variation (Appendix, figs. 39 and 40). Also, on the basis of weekly averages, they had less tendency to follow the violent fluctuations of outside weather conditions for both relative humidity (Appendix, figs. 35 and 36), and dry bulb temperatures (figs. 37 and 38). This is reflected in sample analyses (Appendix, figs. 33 and 34). Seasonal moisture and fat acidity variations were less in the warehouse D (Bay City No. 15) and warehouse E (Carrollton) than in A (Bradleyville) and B (Breckenridge).

Sample analyses showed interesting seasonal trends in both moisture and fat acidity, with maximum readings in the spring dropping to minimum readings in the early fall, followed by a recovery period. Mold counts were consistently low in all but one case in which the beans were initially of poor quality. It is to be expected that the beans would not go out of condition in storage since it is the purpose of the warehousemen to move all of their beans before spoilage occurred.

Considerable mold appears to have been present on the beans that were stored in warehouse D (building 15), lot 38, Bay City (Appendix, fig. 34 and table 5), although the moisture content was usually below 16 percent

Warehouse C.--This is a recently constructed, well-insulated warehouse. It is built of cinder-like insulation blocks. The roof is separated from the insulated inside ceiling by a 2-inch ventilated air space. A sketch and picture are shown in Appendix, fig. 25. The floor is concrete, doors are insulated, no windows and no ventilation are provided. The warehouse is normally closed until portions of the beans are moved out in the spring. Then the area is open much of the time for other elevator activities. This warehouse has a capacity of from 12 to 14 carload lots. The test lot was Michelite beans from the 1952 crop grown in that area and stored during October 1952.

Warehouse D.--This warehouse was formerly a shipyard. It is a large double-thickness, brick-walled structure, with an uninsulated tar and gravel roof. Details of construction are shown in the Appendix, fig. 26. Windows are covered or painted, the floor is concrete, and there is no provision for ventilation except 3 swinging roof ventilators of about 2-feet diameter openings. The warehouse has a 46-carload lot capacity for storage. Lot 66 was 1952 beans, and lot 38 was 1951 beans grading U. S. No. 2, going into storage.

Warehouse E.--This warehouse was at one time a shipyard. It is a large wooden, uninsulated structure, with a cement floor and wall areas containing nearly one-fifth painted or semitransparent glass. The sketch and picture (Appendix, fig. 27) give details of the structure. A 7½-horsepower electric motor is used with a grain blower to circulate air throughout the building in the early fall and late spring when the weather warms. It was believed that circulating the air within the building when it was stale would have a beneficial effect on the beans. The storage was closed to the outside directly at all times. It was entered through an adjacent room. This warehouse has a 40-car capacity. The test lot consisted of 1951 beans placed in storage in September and October 1951. This lot was of good quality and graded U. S. No. 1 when sold in September 1953.

Warehouse F.--This warehouse was also a shipyard at one time. It is a low, uninsulated wooden structure, covered on the sides and on the roof by tar paper. There is much window area, all semitransparent glass. Details of construction are shown in Appendix, fig. 28. Doors and windows are kept closed, the only provision for ventilation being 4 swinging roof ventilators of about 2-foot diameter openings. This building has a 34-carload lot capacity. The test lot was 1951 beans, grading U. S. No. 1 when put into storage in June 1952.

Research undertaken in warehouses:--Specific carload lots or piles of beans, consisting of 800 bags, were selected for study in each of these warehouses. At Warehouse A (Bradleyville) beans were stacked in larger lots and single bags were selected for study in comparison with the overall lot. The locations of these test lots are shown in the sketches and drawings of the warehouses. Once each month samples of beans were taken at random from the bags on the edges of the carload or from the individual bag on the edge of the lot at the Bradleyville warehouse. These samples were analyzed for moisture, fat acidity, and molds. The results of these analyses are shown in the Appendix, figs. 33 and 34, and table 5.

during the storage test. Mold content increased from the comparatively high figure of 6200 spores per unit on January 1, 1953 to 1,460,000 spores on March 30, 1953. The greater mold development in this lot might be explained by the high mold count and the moisture content at the time they were stored.

Conclusions:--The typical commercial bean storage warehouse in Michigan has no devices for controlling the dry bulb temperature or the relative humidity in the warehouses. Storage conditions are dependent, to a large extent, on the outside weather conditions. There is a lack of uniformity in the management practices of the warehouses because (1) some warehouses must be used for purposes other than the storage of beans, (2) some warehouses differ from others in construction, and (3) there is a lack of agreement among operators as to what conditions are best for the storage of beans. The larger warehouses that were closed to outside weather conditions had less fluctuation of dry bulb temperature and relative humidity. Seasonal fluctuations in dry bulb temperatures in the warehouses were observed of from near 30° F. during the winter months to the 70° to 80° range in the summer months. Similarly, variations in relative humidities were observed of from the 80 to 90 percent range in the winter, to 50 to 60 percent range in the summer. Seasonal fluctuations in the moisture and fat acidity content of the beans were noted, but mold counts were, in general, consistently low. Quality distribution studies throughout carload lots of beans indicated higher moisture and fat acidity values within the lots than on the edges.

Recommendations:--Under the relatively short storage period studied, the beans observed tended to remain in good condition, regardless of the type of warehouse or the warehouse management procedure. However, these were, in general, beans of good quality stored in a normally dry season. Detailed information and facts are not available on the effect of storage conditions on bean quality. However, well insulated warehouses that protect beans from the violent fluctuations of outside temperatures and humidities would appear desirable, especially under adverse storage conditions and with beans of questionable keeping quality.

Ventilation Studies

Procedure:--

Ash Grove, Indiana

Four of the 7 carloads of beans stored at Ash Grove were placed in 1 quonset in 4 stacks of 1 carload each. Mechanical ventilation equipment was installed in these stacks. The remaining three carloads were placed in a second quonset and were broken down into stacks smaller than carlot size. The various stacking arrangements included bags piled flat, bags piled on edge, no pallets, pallets on the first tier of bags, pallets on the second tier of bags, and stacks with square chimneys in the center. (See figs. 1-8.)

All of the beans stored in the quonset buildings were placed on dunnage constructed of 2"x4" lumber on edge with 1"x6" and 1"x8" boards laid

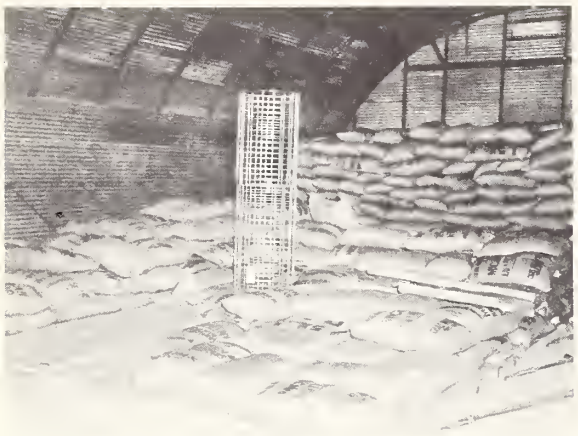

Figure 1.--Four carloads of sacked beans were mechanically aerated in this quonset. Note how dunnage was put under the bags with reinforced paper on top of lumber to force air through bags.

Figure 2.--One carload was aeration with a 1/2-HP 20-inch fan forcing air down through the pile. Another car was aerated by exhausting air from the top. It was rather difficult to place the bags around the wire cage and maintain the desired stacking pattern.

Figure 3.--This carload of bagged beans was aerated with a 1/20-HP motor mounted on the 8-inch perforated tube to the left of ladder.

Figure 4.--A 20-inch tube and fan mounting was put in horizontal to compare with 2 vertical aeration tests with same size fan and motor.

Figure 5.--A horizontal tunnel was made by placing short boards across the 15-inch space and stacking bags above. See Fig. 6. Note the thermocouple wires on floor. Thermocouples were placed so readings could be made from one side of each carlot.

Figure 6.--Note how the tunnel is covered so that when the fan was installed air would be pulled from the sides and top at about the same rate. Note how the 5-ft. downspout and the 30-inch portion are spaced so as to obtain representative samples from respective bags each time.

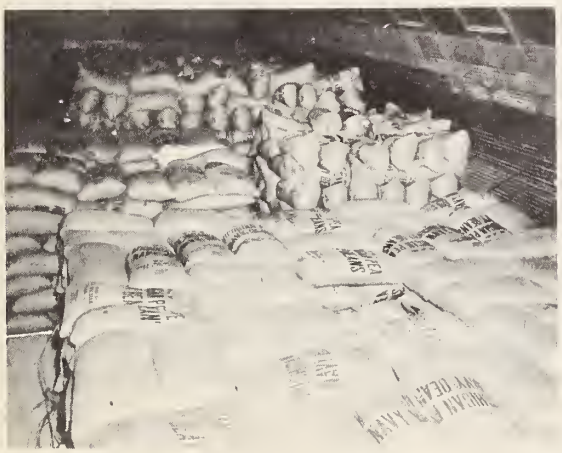

Figure 7.--In the center of the foreground is a chimney for aeration of center of carload and for sampling. The two stacks just behind are stacked flat and on the right on edge also have a chumney for aeration.

Figure 8.--This is a pile stacked on edge and with a pallet in first tier. Note the sample tubes and the thermocouple wires on side of pile.

solid on top. The pallets were constructed of 2"x4" lumber on edge with spaced boards on each side to increase the natural ventilation through some of the beans. A detailed description of all the stacks is given in table 2, page 7.

The fans on the four lots of beans mechanically ventilated were controlled by humidistats and time clock. Initially, the controls were set to allow the fans to operate during the coolest part of the day (between 3 and 9 a. m.) and only when the relative humidity was between 80 and 90 percent. The humidistat settings were changed after 2 weeks of operation to allow the fans to operate when the relative humidity was between 70 and 80 percent. The record of the first two weeks' operation revealed that the fans were operating when the average relative humidity of the air was higher than that in equilibrium with the beans.

In April 1953, the humidistats were changed to permit fan operation when the humidity was below 80 percent. The time clock, of course, limited ventilation to between 3 and 9 a. m. When the lower relative humidity limit of 70 percent was used, the average fan operation time per day was only about 10 to 15 minutes. The elimination of the lower limit increased the operation time to about 4 to 5 hours on clear days.

The above schedule was followed until October 1953. At that time, it was decided to change the fan operation to the warmest part of the day to try to reduce the moisture content of the beans. The fans were allowed to operate between the hours of 10 a. m. and 3 p. m. and only when the relative humidity was below 80 percent. Operating on this schedule, the average moisture content of the beans being ventilated mechanically was lowered to about 11.0 percent.

In March 1954, the controls were changed back to permit the fan operation only between the hours of 3 and 9 a. m.

Thermocouples and sampling tubes were installed as the stacks were being constructed (Appendix, fig. 46.) Diagrams were made during the stacking process to show the location of the thermocouples. The sampling tubes were made of 3-inch downspouting and were permanently located in the stacks. They were plugged on the outer end with a removable paper drinking cup to prevent air movement through the tube. Sampling was accomplished through the tubes by the use of a standard 12" sack probe on the end of a piece of pipe.

The monthly samples for moisture content and fat acidity determinations were sent to the Standards Research and Testing Division, AMS, Grain Division, at Beltsville. Pint samples were taken and expressed to Beltsville in standard metal grain sample cans.

Temperatures were taken at 16 different points in the stacks containing a full carload of beans. In the stacks containing less than a carload, temperatures were taken at eight different points. See Appendix, table 9.

Recording hydrothermographs were placed inside and outside of the storage to obtain the outside temperature, outside relative humidity, inside temperature, and the inside relative humidity. Fan operation time was recorded with a recording soil thermograph, with the sensing element of the thermograph placed near a light bulb connected to the electrical circuit supplying the fans. The time that the fans and light bulb were operating was indicated by the period of higher temperature recorded on the thermograph. From these data and the recorded temperature data, it was possible to determine the average inside temperature, outside temperature, and relative humidity while the fans were operating (table 6).

Discussion:--

The results of these tests were based on data collected on the temperature, moisture content, commercial grade, and fat acidity of the beans. In addition to tabulating the individual test results, comparisons were made between the group of 4 mechanically ventilated piles, the group of 10 naturally ventilated piles, and the single check pile of the beans stored at Ash Grove, Indiana.

Samples from each carload lot were taken in March 1953 and February and June 1954 and shipped to the Toledo (Ohio) Grain Division Inspection Office for grade determination. The results from these samples are listed in table 10, of the Appendix.

Considering the entire lot of 7 carloads of beans, the grading factors did not change much during the storage period, except that the average moisture content changed from 15.9 percent to 13.7 and then rose to 14.4.

Fat Acidity as a Quality Factor

The values of the fat acidity of all the samples taken are given in table 7. The fat acidity of all the beans in the various treatments ranged from 17 to 24 when the project was started. At the end of the 16-month storage period, the range of fat acidity was from 20 to 43. The average of the naturally ventilated piles was generally higher than that of the mechanically ventilated piles. However, both were higher than the average fat acidity of the check pile. This average relationship is illustrated graphically in Appendix, fig. 47.

Although there was a consistent increase in the fat acidity during the warm months of the year, it appears that navy beans were stored under the conditions of this test with little loss of quality. There was no marked increase in damage or visible mold growth. It also appears that so far as quality deterioration is concerned there was little difference between the various ventilation and stacking treatments used.

During the summer months, a pronounced odor or musty smell could be detected in the sampling tubes and also the building. In the quonset housing, the mechanically ventilated beans, the odor was particularly noticeable when the fans were first started. However, the odor seemed to decrease after a few minutes of fan operation.

The moisture contents of all samples taken are tabulated in table 8 and compared graphically in figure 48. Initially, the fan was set to operate between 3 and 9 in the morning and when the relative humidity was between 70 and 80 percent. Under these fan operating conditions, the average moisture content of the mechanically ventilated piles remained within 1 percent of the initial average for the first 6 months. The average moisture content of the naturally ventilated piles and the check pile also remained within 1 percent of their initial average.

Temperatures of the beans followed the average temperature inside the storage building, as shown in table 9. Despite the various stacking arrangements and different means of ventilation, the average temperatures were about the same. Temperatures of the beans mechanically ventilated were slightly higher during the spring and early summer, and cooler during late summer and autumn than beans not ventilated.

The results of comparison of bags of beans stored on edge with those stored flat and with a pallet on the first and second tiers are indicated by moisture relationship (fig. 49), and by fat acidity relationship (Appendix, fig. 51). The moisture of the check on edge is higher than with the bags stored on edge with pallet on the first and second tiers, and the flat stored check is lower in moisture than the bags stored flat with pallets on the first and second tiers. In figure 50, the same pattern exists for fat acidity. The flat check had a lower fat acidity than when a pallet was on the first or second tier. Whereas, the check on edge generally carried a higher fat acidity than the flat storage with pallet on the first or second tiers.

In figure 51, it is interesting to note how the moisture and fat acidity analyses fluctuated when the time of operating the fans was adjusted.

Caro, Michigan

Beans stored at the Caro CCC bin site were stored in four 2000-bushel steel bins. The delivery of these beans was started in February and completed in April 1953. The treatments included one-half carload (400 bags) stacked flat, one-half car stacked on edge, and 2 carloads of bulk beans ventilated mechanically. One lot of bulk beans was ventilated with a 1/20-HP 8-inch propeller fan exhausting from an 8-inch vertical tube in the center of the bin. The other lot of bulk beans was ventilated with a 20-inch 1/2-HP fan which pulled the air down through the beans and exhausted it from the area between the solid bin floor and the perforated false floor. The smaller fan ran continuously and the larger fan for 2½ hours early each morning.(figs.9-14).

Discussion:--

The beans at the Caro CCC bin site were sample grade at the start of the test, according to the initial grade samples taken in April 1953. A tabulation of the grade factors at three sampling dates during the storage period follows:

Bin site storage for dry beans, Caro, Mich.

Figure 9.--Caro, Mich. bin site. Bulk beans were stored in the second and third bins, and sacked beans in the fourth and fifth. Note the weather instrument house between the second and third bins.

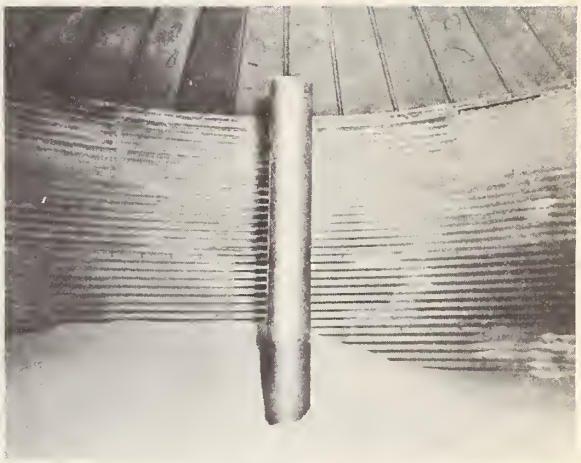

Figure 10.--Bulk beans stored in third bin and ventilated with 1/20-HP fan, expelling air from the top of this tube. Note perforated tube above bulk beans. The bin was filled to about 7-ft. depth (just below top of door).

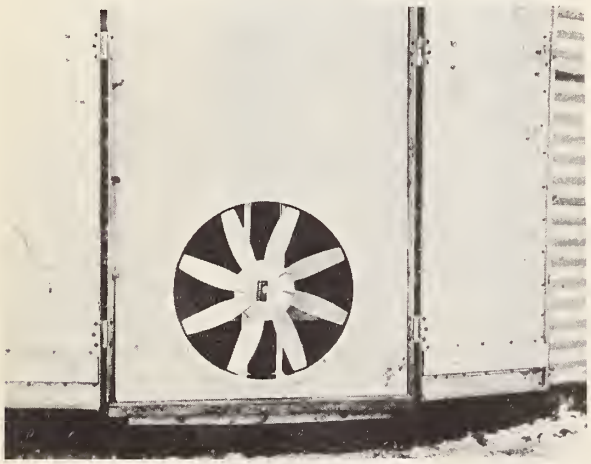

Figure 11.--A plywood panel door was made to permit the fan to operate in the second bin. The beans were stored on a perforated floor, permitting 8 inches of air space under the beans and ample room for aeration.

Figure 12.--Note the well in center of stack which is about 30 inches square and reaches to the floor. Sampling was done from the well through 3-inch downspout tubes in order to sample the same bag at the same location each time.

Figure 13.--A 30-inch chimney in center of beans stacked on edge gave additional natural aeration and provided for center sampling of pile through 3-inch down spouting as sampling tubes. This treatment resulted in a lower fat acidity value after the first year at Caro, Mich., than did the other bins.

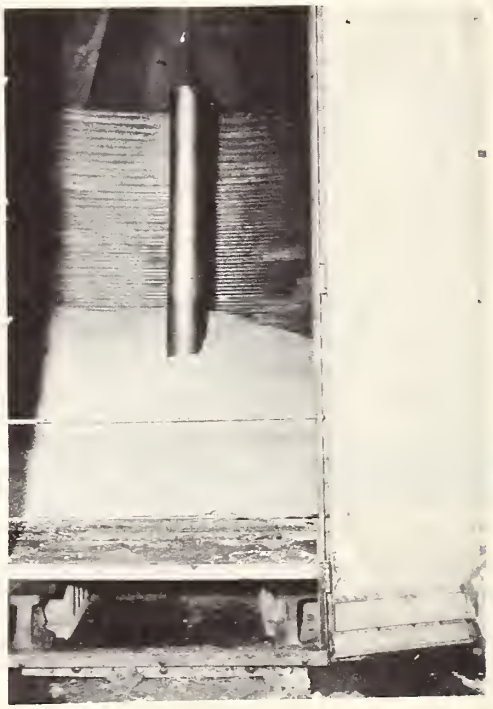

Figure 14.--In a bulk steel bin at Caro, Mich., an 8-inch tube perforated at the bottom and erected in center of bin provided for a more equal moisture distribution in lot, and provided for fumigation and conditioning as required. A 1/20-HP motor and fan was mounted on top of the tube to provide ample air movement when the bin was filled. (About 7-foot of beans).

Table 3.--Inspection analysis of pea beans stored at Caro, Mich.

Date and identification	Moisture	Splits	Damage	Cracked seedcoats	Condition	Federal grade
	Percent	Percent	Percent	Percent		
April 1953						
Large fan bulk bin ...	15.0	3.0	1.3	4.7	Musty	Sample
Small fan bulk bin ...	15.5	3.2	3.5	7.5	Musty	Sample
East bag bin	16.0	.7	2.6	1.4	Musty	Sample
West bag bin	16.5	1.0	1.7	1.5	Musty	Sample
March 1954						
Large fan bulk bin ...	15.4	2.8	2.0	5.9	Musty	Sample
Small fan bulk bin ...	14.5	2.5	2.7	7.0	-	No. 3
Bag lots (composite both bins)	15.7	1.0	2.7	2.8	Musty	Sample
June 1954						
Small fan bulk bin ...	14.5	3.0	3.3	7.3	Musty	Sample
East bag bin	14.0	2.0	2.0	3.6	Musty	Sample
West bag bin	15.0	.7	2.0	4.0	Musty	Sample

There was no great change in any of the grading factors during the storage period (table 3). The odor of the bulk beans ventilated continuously with the small fan was improved sufficiently to grade No. 3 instead of sample grade after 11 months of storage. However, three months later the beans again graded sample. The lot of beans ventilated with the larger fan was removed from the experiment after the March 1954 inspection. Rats had gained entrance to the bin through the fan mounting in the bin door. There were also some weather leaks at this point. Both difficulties point to the need of a better method of installing the ventilating fan than was used in this test.

A record of fat acidity values and moisture content is given in table 11. Examination of the table shows that the bulk beans ventilated with fans dried more than the bagged beans. The moisture content of all the beans tended to drop in the summer and fall and rise in winter and early spring. Fat acidity of all beans stored at Caro increased during the test period at about the same rate as those stored at Ash Grove, Ind.

Marysville, Michigan

Two of the 10 bins shown in figure 15 were used to store bulk beans for CCC.

The tanks were equipped with floor ducts (2"x1" planks, 2 inches apart, with hardware cloth on top) over the central 6-foot opening (one other opening on each side over the bottom conveyor) and through a pipe system a 10-HP motor-driven fan could be set to exhaust air from either or both tanks. The fan delivered 3,000 to 4,000 CFM at a static pressure of 8 inches of water. Three vents in the top of the bin, including one manhole, were opened when the fan was operating to provide for sufficient intake of air (fig. 18). This was found to be an effective method for cooling and equalizing the moisture of bulk beans as needed. The manhole was also used for entering the silos for sampling and checking the condition of the commodity. A ladder enclosed by a metal framework extended from each manhole to the bottom of the silos to provide for removing samples through the top of the silo.

The silos were filled by means of a conveyor that elevated the beans from the pit and moved them across the top of the silos. By adjusting metal slides mounted in the conveyor over each silo the beans could be directed into the proper storage unit (figs. 16 and 17). The space between the chain drag conveyor and the bottom housing soon filled with beans, preventing substantial breakage from the friction and slap of the belt. The beans remaining in the conveyor, however, were likely to spoil or become weevil-infested and were somewhat difficult to clean out of the horizontal conveyors when not in use.

In order to follow the temperature pattern throughout the bean mass, two strings of thermocouples were installed in each silo. They were placed about 6 feet apart in the center area and extended from the top to the bottom. The thermocouples were spaced 6 feet apart on each string, but the strings were staggered so as to obtain a temperature reading at each 3-foot depth of beans (table 12). A central potentiometer was installed so that temperatures at any thermocouple in either silo could be noted at any time.

Quality Measurements

Moisture and fat acidity analyses were determined by months from four different levels of the silo. Samples were taken from the surface foot, 4-foot and 7-foot levels from surfaces as well as from the bottom of the tank. These samples were mailed to the Grain Division, AMS, at Beltsville, Maryland, for analysis. Moisture and fat acidity at each level for each silo are tabulated in Appendix, table 13.

Movement of Hot Spot

In the Appendix, figure 53, it is interesting to note that a hot spot started to show between the 24- and 36-foot thermocouple on September 29, and by October 4 the temperature of the area had risen an additional 3 or 4 degrees. By October 9 the general hot spot moved down and had raised the temperature in 5 days 15 degrees at the 18-foot level, and 11 degrees at the 12-foot level. With the tendency for hot spots to normally move upward the effect of aeration is very pronounced. It was

Silo bulk pea bean storage, Marysville, Mich.

Figure 15.--Marysville, Mich. bulk storage silo. Two of these bins were used by the Michigan Elevator Exchange to store 40 carloads of CCC-owned pea beans. Temperature recording instruments were installed in top of central structure.

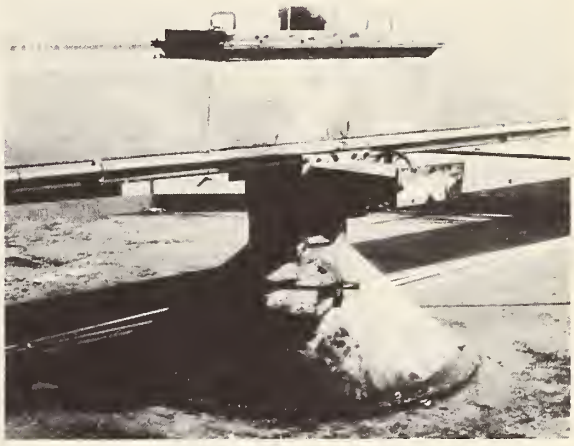

Figure 16.--This conveyor reaches across the top of each silo and makes it possible to take the commodity out the bottom and it may be elevated and moved to any of the other tanks.

Figure 17.--Picture taken from center and top of silo, showing how the conveyor can be regulated to empty beans in any of the five silos. The land in the background is in Ontario, Canada, and the weather is usually cool at this point.

Figure 18.--Note the manhole through which entrance to the silo was made to obtain samples. The manhole cover was opened when aeration was in progress by operating the 10-HP exhaust fan, pulling air in the top and down through the beans.

noted on October 13 that the center of the hot area had moved (in 4 days) from the 18-foot level to the 12-foot depth and although the high temperature remained at 109°, the beans at the 30-foot level cooled from 102 to 68° in 4 days, and at the 24-foot level cooled 13° during that period. However, the aeration from the top with cool air continued to force the hot air downward and increased the temperature in the 6-foot area from 84° to 100° F.

The potentiometer was broken from October 14 to 28. During this 2-week period temperatures were reduced 42°, 23°, 11°, and 10° at the 24; 18; 12; and 6-foot levels, respectively. The highest temperature remained at the 12-foot level from October 13 until December 4 when the highest temperature was reduced to 50° and was then moved down to the 6-foot level.

It was believed that the bulk beans were not leveled off soon enough after they had been entered into the center of the silo (from the top), resulting in the migration of moisture into the central peak of the pile and causing the temperature to rise. It is, therefore, recommended that when dry edible beans are stored in bulk, precautions be taken to level the surface immediately.

INSECT CONTROL STUDIES 4/

During the summer of 1952, a research project was initiated in cooperation with the Commodity Stabilization Service to control insects infesting Government-stored dry beans. Information obtained from the CSS officials and secured through warehouse surveys made by Biological Sciences Branch indicated that nearly all of the difficulty resulted from moths. The one causing the most trouble was the Indian-meal moth, Pladia interpunctella Hbm., while those of more or less secondary importance were the almond moth, Ephestia cautella Hbm., and the tobacco moth, Ephestia elutella Hbm. Tests were made on the control of infestation in both bulk and sacked beans by use of pyretheum sprays or aerosols, and by use of fumigants.

Control of Insects in Bulk Storage

The idea of storing dry beans in bulk has been considered by the industry for some time. The CSS became interested in this method of storage and set up a test at Marysville, Mich., in which Michigan pea (navy) beans were stored in the bulk in two large concrete silos. Not long after the test had begun a surface infestation of Indian-meal moth was observed in the beans in both silos. An attempt was made to eliminate the insects by means of a synergized prethrum spray applied at approximately 2-week intervals.

Three applications were made during the fall of 1952, the first on August 29, the second on September 12, and the third on October 1. The insecticide used contained 1-percent pyrethrins, 10-percent synergist, 15-percent emulsifier, and 74-percent deodorized kerosene. This formulation was applied to one side at the rate of 6 ounces per 1,000 cubic

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4/ By Howard D. Nelson and E. L. Mayer, Stored-Product Insects Section, Agricultural Marketing Service, U. S. Department of Agriculture.

feet of overspace, and to the other at the rate of 3 ounces. It was introduced as a mist by means of a small portable air compressor with a hose and adjustable nozzle attachment operating under 50 pounds of pressure. A light application was made directly to the surface of the beans and the remaining dosage was atomized into the overspace.

This study demonstrated that a pyrethrum spray applied at the rate of 3 ounces per 1,000 cubic feet of overspace was effective in controlling an Indian-meal moth infestation in bulk-stored Michigan pea (navy) beans. There was no indication that such a treatment proved to be injurious to the beans.

The greatest difficulty encountered was the development of a mold growth on the beans which resulted from high moisture. Such a condition produced heating, deterioration of the beans, and increased possibility of insect infestation. This problem was reduced by filling each storage unit to not more than three-fourths capacity and by keeping the surface of the beans level.

Control of Insects in Bagged Beans

Practically all of the dry beans owned by the Government are stored in 100-pound burlap bags. Quite frequently such beans become infested with moths, particularly if they remain in storage beyond the first summer after harvest. If such an infestation is permitted to develop, the outer surface of the bags are likely to become covered with a layer of webbing produced by the larvae especially those in the top area of the stack. Numerous mature larvae may be seen crawling over the surface of the bags and pupa cases may be observed in the area where one bag touches another. The larvae feed upon the fleshy part of the beans and apparently are not able to penetrate those that have sound seedcoats. An example of moth injury to the beans, deposit of webbing on the bags and the position of the pupae cases is shown in figures 19-22.

During the summer of 1952 a program was started on the control of the Indian-meal moth in Government-stored dry beans through the use of pyrethrum aerosols. The beans under test were stored in a well-constructed warehouse at Toledo, Ohio. At the time the treatments were started, a moderate-to-heavy Indian-meal moth infestation had become established in the beans. The beans were stored on four floors of the warehouse. At the beginning of the study, two aerosol formulations were used:

Formulation No. 1 (60 ml/1000 cu. ft.)

¼ gallon of a concentrate containing 1% pyrethrins + 10% synergist	- 7.5 ml/cu. ft. of space
3/4 gallons deodorized kerosene	- 22.5 ml/1000 cu. ft.
1 gallon carbon tetrachloride	- 30 ml/1000 cu. ft.

Formulation No. 2 (60 ml/1000 cu. ft.)

½ gallon of a concentrate containing 1% pyrethrins + 10% synergist	- 15.0 ml/1000 cu. ft. of space
½ gallon deodorized kerosene	- 15.0 ml/1000 cu. ft.
1 gallon carbon tetrachloride	- 30.0 ml/1000 cu. ft.

Figure 19.--Injury to dry beans by larvae of the Indian-meal moth. The amount of frass and webbing is typical.

Figure 20.--This photograph shows the amount of webbing deposited by larvae of the Indian-meal moth on burlap bags located on top of a stack of beans. The webbing on the first bag has been punctured and turned back to expose the surface of the bag.

Figure 21.--Bags removed from top of stack showing more clearly the extent of webbing.

Figure 22.--Example of Indian-meal moth pupae placed where one bag has touched another.

These formulations were applied by means of a mechanical-type generator which was set to produce particle sizes not to exceed 50 microns in diameter. Applications were made at approximately two-week intervals from October 15 to November 12, 1952. Treatments were resumed the following May and continued until the beans were moved out of storage in July 1953.

Observations were made relative to an aerosol program that had been instigated in a warehouse at St. Joseph, Mo. This warehouse stored Government-owned beans. Shortly after the beans had been placed in storage, moths were observed flying between the stacks. The manager immediately applied an aerosol containing 0.31 percent pyrethrins, 2.5-percent synergist, and 97.19 deodorized kerosene at the rate of 1 pint for each 8,000 to 15,000 cubic feet. Applications were made whenever moths were observed. The insecticide was applied by means of a mechanical-type aerosol generator.

This work at Toledo, Ohio, and observations made at St. Joseph, Mo., demonstrated that pyrethrum aerosols were effective in reducing populations of Indian-meal moths in bean warehouses. A formulation consisting of 50 percent, by volume, of carbon tetrachloride produced an aerosol with a low mass medium diameter that appeared to distribute itself in a more uniform manner than those formulations containing distillate or deodorized kerosene. The periods of application should be governed by the presence of moths rather than by a set schedule.

Fumigation of Beans

Where moth infestations become well established, fumigation is usually the only method by which they can be readily destroyed.

In certain of the bean-producing and storing areas, high moisture and subsequent mold development on the beans present a problem in relation to fumigation. It has been observed that when beans are produced and stored in the Michigan and New York areas and fumigated with methyl bromide a disagreeable odor may be imparted to the beans. This is particularly true of red kidney and Michigan pea (navy) beans.

An attempt was made to select a fumigant that would not cause an odor. The first approach was to conduct laboratory fumigation tests on beans that had been produced in these areas. This was done at the field laboratory at Fresno, Calif. On the basis of that work, two lots of Government-owned Michigan pea (navy) beans were fumigated at Ash Grove, Ind., during May 1954. One lot was fumigated with standard grain fumigant mixture containing 80-percent carbon tetrachloride and 20-percent carbon disulphide applied at the rate of 3 gallons per 1,000 cubic feet of space, and the other with chloropicrin at the rate of 2 pounds per 1,000 cubic feet of space. Both lots were fumigated under a polyethylene plastic tarpaulin, and the exposure periods were 24 hours. Samples of the beans were obtained and sent to the Fresno (Calif.) laboratory where odor determinations were made. The study with red kidney beans has not yet been completed.

Both the laboratory and field studies demonstrated that either of these fumigants can be used without imparting an odor to Michigan pea (navy) beans under the conditions of these tests.

MOISTURE EQUILIBRIUM STUDIES 5/

As a result of the practice of storing Michigan pea beans at moisture contents of approximately 17 to 18 percent, considerable difficulty is encountered in storage, particularly when the beans cannot be moved in bulk from bin to bin. When stored in 100-pound sacks, excessive rancidity, heating, and molding occurs.

The present research was initiated to study the behavior of beans when stored in air at various relative humidities and temperatures.

Procedure:--

Two lots of beans, one "dry" (about 14-percent moisture) and one "wet" (about 20-percent moisture) were used to assure uniform subsamples. These were stored at a subzero temperature to prevent molding and insect damage. Quart containers were prepared in which various relative humidities (55, 65, 70, 75, 80 and 85 percent) were maintained by use of a suitable concentration of sulphuric acid (13). Two weighed samples of 100 beans each, one sample "dry" and the other "wet" were placed in cheesecloth bags and suspended in the air above the acid.

Periodic weighings showed when equilibrium had been reached. This procedure was repeated in constant temperature chambers at 40, 50, 70, 80, 90, 100, 110, and 130 degrees F. After equilibrium was reached, a portion of each sample was used for the determination of moisture content by loss of weight in 44 hours in a vacuum oven at 100° C. A 5-gram sample was used to determine the mold-spore population. The beans were washed in 10 ml. of water to remove the spores. Five dilutions of this spore suspension were made and plated on a medium composed of 2-percent plain malt extract, 1-percent sodium chloride and 2-percent agar. Counts of mold colonies were made after five days' incubation and are expressed in colonies per gram of beans.

Results:--

Table 14 shows the moisture content of the beans at equilibrium with air at various temperatures and relative humidities. In each case, the values for the samples originally "dry" and "wet" are given, as well as the average of the two values. The duration of the exposures at the various temperatures is shown in table 15.

5/ S. T. Dexter, professor of farm crops; A. L. Andersen, plant pathologist, Hort. Crops Res. Br., ARS, U. S. Dept. of Agriculture and Dept. of Botany and Plant Pathology; P. L. Pfahler, graduate assistant in farm crops, and E. J. Benne, professor of agricultural chemistry, Mich. State University, East Lansing, Mich., "The Moisture Content, Discoloration, Rancidity, and Mold Count of White Pea Beans Stored at Various Relative Humidities and Temperatures," Agron. Jour. Vol. 47, No. 6, June 1955.

Two lots were run at the various relative humidities at 110° F. In the first run it was observed that considerable darkening of the beans was occurring, especially at the higher relative humidities, and it seemed difficult to obtain a constant equilibrium weight. The moisture contents appeared to be giving an inversion in the moisture curves. It was felt that the discoloring might be related to these matters.

For this reason, samples from another lot of "dry" beans were obtained, and the 110° F. series was repeated. In this second case, the samples were removed when equilibrium was almost established, but before the discoloration was extreme. The moisture values show that much the same picture of moisture content developed in both cases. The discoloration, although not so extreme, was still very noticeable and greater than at the lower temperatures.

Figure 54 shows the degree of discoloration that occurred in the beans stored at the various relative humidities and temperatures. Beans stored at higher relative humidities were darkened. At 130° F. and 85-percent RH, the cotyledons were chocolate-brown in color, while at the other extreme of temperature and relative humidity the color was almost white. Figure 54 also shows the difference in appearance of beans stored 20 and 80 days, respectively, at 110° F. and at various relative humidities. At high relative humidities and with long storage, pronounced browning of the cotyledons occurred.

Figure 55 shows the data of table 14, graphically in terms of temperature, while figure 56 shows them in terms of relative humidity. For the four temperatures 50, 70, 80, and 90° F., the moisture curves were entirely regular and virtually parallel, with a higher moisture content occurring in every case at the lower temperature. At 40° F., moisture contents were uniformly lower than at 50° F. Throughout the 110° and 130° F. series, the moisture contents were somewhat above what would have been expected, on the basis of results obtained in the 50° to 90° F. series. At the higher relative humidity the moisture contents were far higher in the 100°, 110°, and 130° F. series than in the 80° or 90° F. series. A decided discoloration and a strongly rancid odor.occurred with higher moisture contents at higher temperatures.

The mold studies (table 16) showed that molds were not responsible for this discoloration since the beans at 130° F. had no molds at all, and few at 110° F. Discoloration of the cotyledons was much greater than was ordinarily visible since the seedcoats were discolored only partially, mainly around the micropyle. The discoloration of the bean embryos was much like that seen in "sick wheat", and occurred under much the same circumstances of high relative humidity and high temperature.

Discussion:--

Beans are harvested in the fall and stored in a rather damp condition in cool, unheated warehouses. They are often subject to a considerable rise in temperature before they are processed. When it is necessary to hold these beans in storage during the hot summer months, the problem is magnified. Not only does the temperature become more favorable for mold

growth, but the relative humidity of the air spaces between the beans increases, thus favoring spoilage.

As a specific example, to show the applicability of these values to storage practice, let us assume that a sample of beans is put into storage at 50° F. and with a moisture content of 16.4 percent. Examination of figure 56 shows that this gives a relative humidity of the atmosphere between the beans of 75-percent RH or a vapor pressure of 75 percent that of water at 50° F. (75 percent of 9 mm). If these beans gradually warm up to 90° F., without losing appreciable water, they will maintain a relative humidity of 78 percent, which corresponds to a vapor pressure of 78 percent of 36 mm. Thus, the warmer (90° F.) beans, although at the same moisture content, appear to be more moist than the cool (50° F.) beans.

It is quite true that the difference seems comparatively small - 75- versus 78-percent RH - but when it occurs at the critical point for spoilage, only a small difference is needed, particularly in view of the more favorable temperature for mold growth. If a small volume of beans becomes heated when surrounded by cool beans, the increased vapor pressure (78 pressure of 36 mm) at 90° F. would be approximately three times the saturated vapor pressure at 50° F. (9 mm) and condensation would occur on the cool beans, thus increasing their moisture content and at the same time warming them, so that conditions for molding would be aggravated.

Generally, the "wet" beans seemed more susceptible to spoilage than the "dry" beans. The "wet" beans had suffered considerable deterioration in the field during harvest. In selecting the 100 beans for each sample, an effort was made to avoid obviously injured beans. Nevertheless, it is apparent that a larger mold spore count developed in these beans, even at low relative humidities. It has frequently been reported that cracked or otherwise injured grain is more susceptible to damage in storage than is sound grain, even when at the same moisture content.

Attention has been called repeatedly to the difference in the moisture content of various materials at different relative humidities and the relationship of these values to the allowable moisture content in storage. Milner and Geddes 6/ state the so-called critical moisture level for any individual species is the percentage moisture at which the seed is in equilibrium with an atmospheric humidity of about 75 percent. Thus, the moisture contents at 75-percent RH of barley, oats, corn, and wheat are about 14.4, 13.9, 14.4, and 14.6 percent, respectively, whereas flaxseed (10.0 percent) and other oily seeds are materially lower in equilibrium moisture content at this relative humidity. Beans are notably higher, with a value of about 16.3- to 16.7-percent moisture, at 75-percent relative humidity. Thus, the storage of beans at 17- to 18-percent moisture is not as completely out-of-line as might appear at first glance, Barton 7/ shows a spread of about 7 percent in the moisture contents of the seeds of 6 species at 20° C. and 76-percent RH.

6/ Wheat respiration in relation to moisture content, mold growth, chemical deterioration and heating. Cer. Chem. 24: 181-191. 1947.
7/ Relation of certain air temperatures to viability of seeds. C.B.T.I. 12: 85-102. 1941.

CONCLUSIONS

The foregoing data and discussion of the three dry pea bean storage research projects covered in this report tend to emphasize a number of factors important in longtime (greater than one year) bean storage and important trends in moisture fat acidity and mold development under numerous controlled and commercial storage conditions.

The general policy for the trade is to handle only the quantity of pea beans that will be markedted and moved out of shippers' warehouses during one marketing year. Therefore, the trade will benefit more from a study of the quality evaluation and change under controlled conditions and in commercial warehouses. Commodity Credit Corporation officials will be more interested in the longtime storage results than in actual commercial handling. A study of the moisture equilibrium relationship to discoloration damage and mold growth points out the danger point or limitation of maximum moisture that may be considered safe under different conditions.

Fat acidity values were found to be an indication of quality or a gage of impending deterioration at the temperatures normally encountered in the spoilage of beans in commercial storages. Therefore, it can give the warehouseman forewarning that he must sell or move his beans to more desirable storage. At lower temperatures, however, fat acidity failed to indicate bean spoilage.

Deterioration of beans in storage depends on the combination of temperature and relative humidity. At higher temperatures, lower relative humidities must be maintained for storage. However, beans may become drier than desirable under such conditions.

In Michigan, a danger period for the storage of beans in warehouses existing in March, when temperatures reach 40° F. and relative humidities in the warehouses may be 70 percent to 80 percent, extends through the summer. Through relative humidity drops to the 50- to 70-percent range in the summer, temperatures rise to the 70° to 80° F. range. In September, warehouse temperatures drop to the 60° F. range and relative humidities of around 75 percent appear normal. The laboratory studies indicate that beans in poor condition (i.e., high moisture, damaged, etc.) can spoil under these situations. These statements are based on data obtained in 1953, a year of normally dry weather. Obviously, adverse weather conditions will aggravate the storage problems of pea beans, both because of the poor storage quality of beans harvested under such conditions, and undesirable temperature-humidity storage conditions.

The storage of bulk beans was tested in both small bins and large tanks and it is believed that if sound beans are stored and aerated properly, the storage period may be safely extended over a longer period and at the same time the moisture and breakage may be regulated.

RECOMMENDED FUTURE STUDIES

Although the above research covered the storage field rather completely, there are a number of points upon which additional data should be obtained in order to learn more about factors influencing quality. The aeration data obtained were incomplete as the beans studied were not representative of commercial quality. Since practically all of the beans included in the pea bean bulk storage were sample grade at the beginning of the test, the results might have been somewhat different if U. S. No. 1 and U. S. No. 2 beans had been used.

Future studies should be considered for the following:

A. Continue work on design of structure in order that temperature and humidity may be more satisfactorily regulated.

B. Methods for conditioning beans for packaging, marketing or extended storage can be improved.

C. The effect of handling on cracking should be studied in order to further reduce cracked seedcoats and breakage.

D. There apparently is a direct relationship between discoloration and temperature, as beans stored at 40° F. did not discolor as rapidly as at higher temperatures. This appeared to be more pronounced with the storage of cranberry beans.

E. Often beans ripen unevenly and when harvested there are likely to be high-moisture beans mixed with the sound, dry beans. The damp beans may spoil and also cause damage to the sound beans. A satisfactory method of quickly separating the wet beans from the dry by electronic or specific gravity methods should be studied.

F. Methods for determining quality of beans may possibly be evaluated in a more dependable way than with the present fat acidity methods.

G. The available information on bulk storage is relatively insignificant compared to the importance of the future shifts that may be expected from bag storage to bulk handling and controlled aeration.

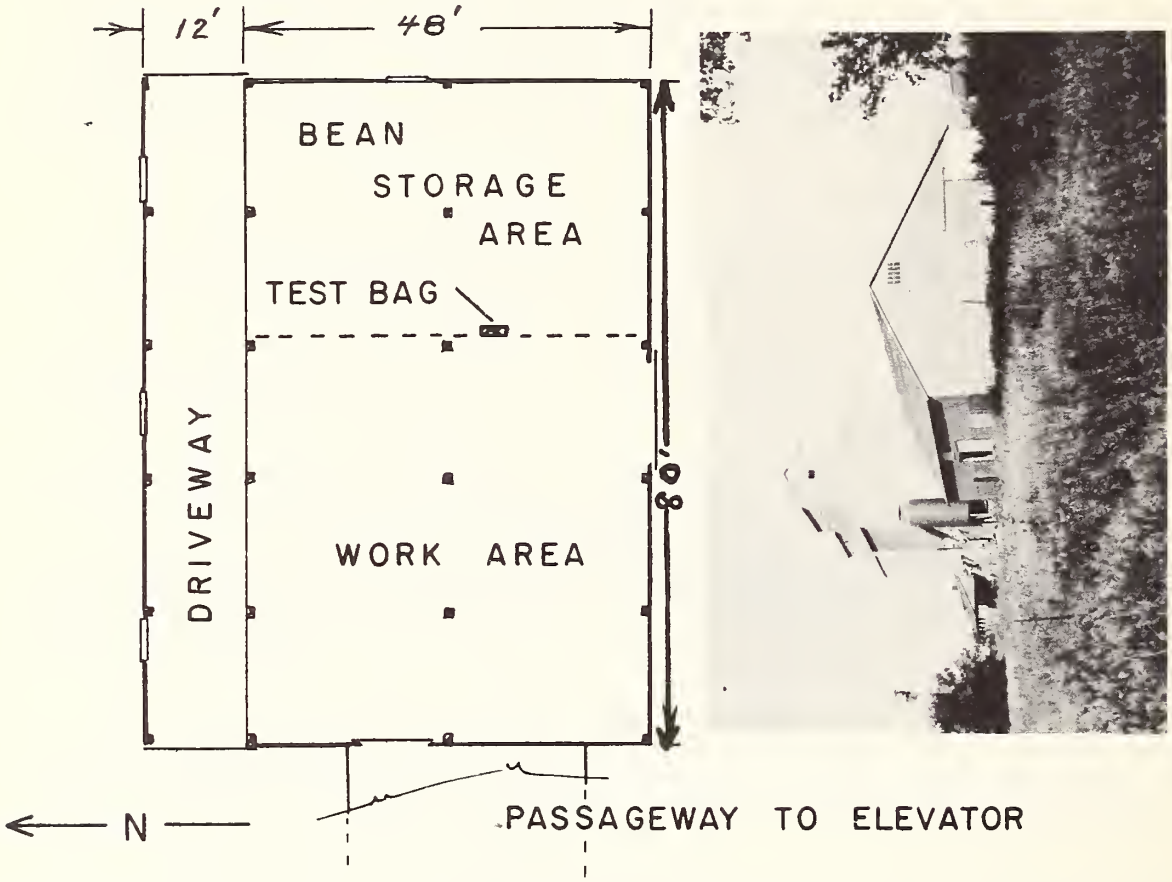
H. Information on respiration rate in relation to drying rate is very incomplete.

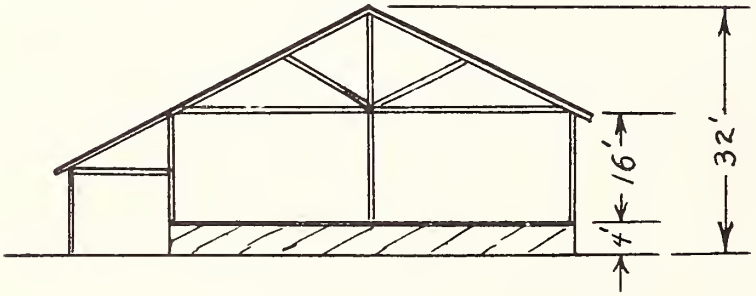
I. The mold study should be continued to learn new methods of inhibiting molds.

J. The use of salt-impregnated absorbent material to adjust the moisture content in stored beans seems promising. Pilot plant might be built to make the necessary preliminary studies.

* * * APPENDIX * * *

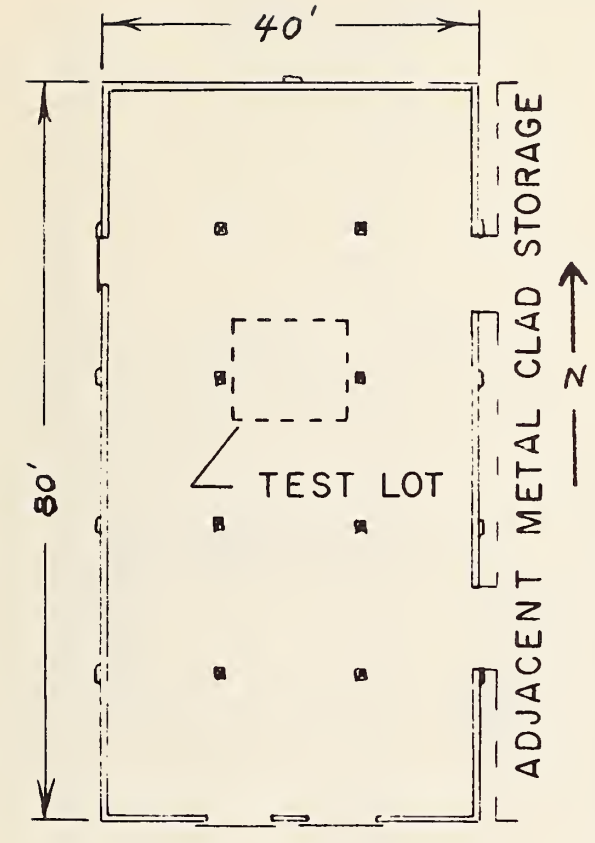
BRADLEYVILLE WAREHOUSE



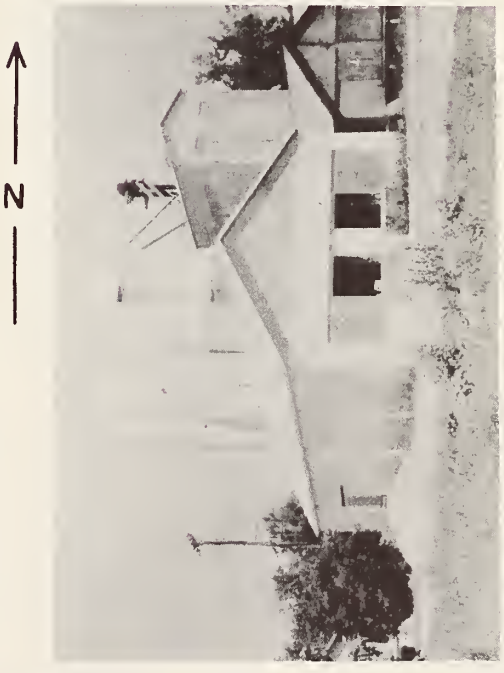


SECTIONAL VIEW

Figure 23. Warehouse A - Bradleyville, Michigan



BRECKENRIDGE
WAREHOUSE



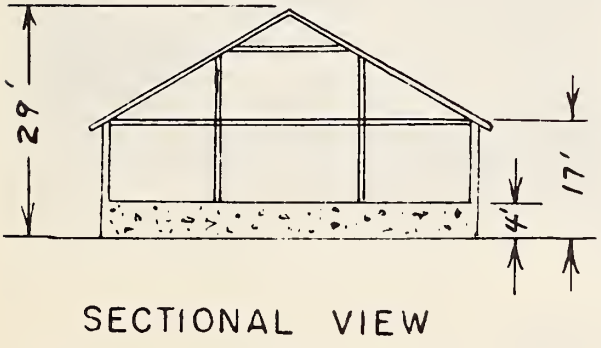


Figure 24. Warehouse B - Breckenridge, Michigan

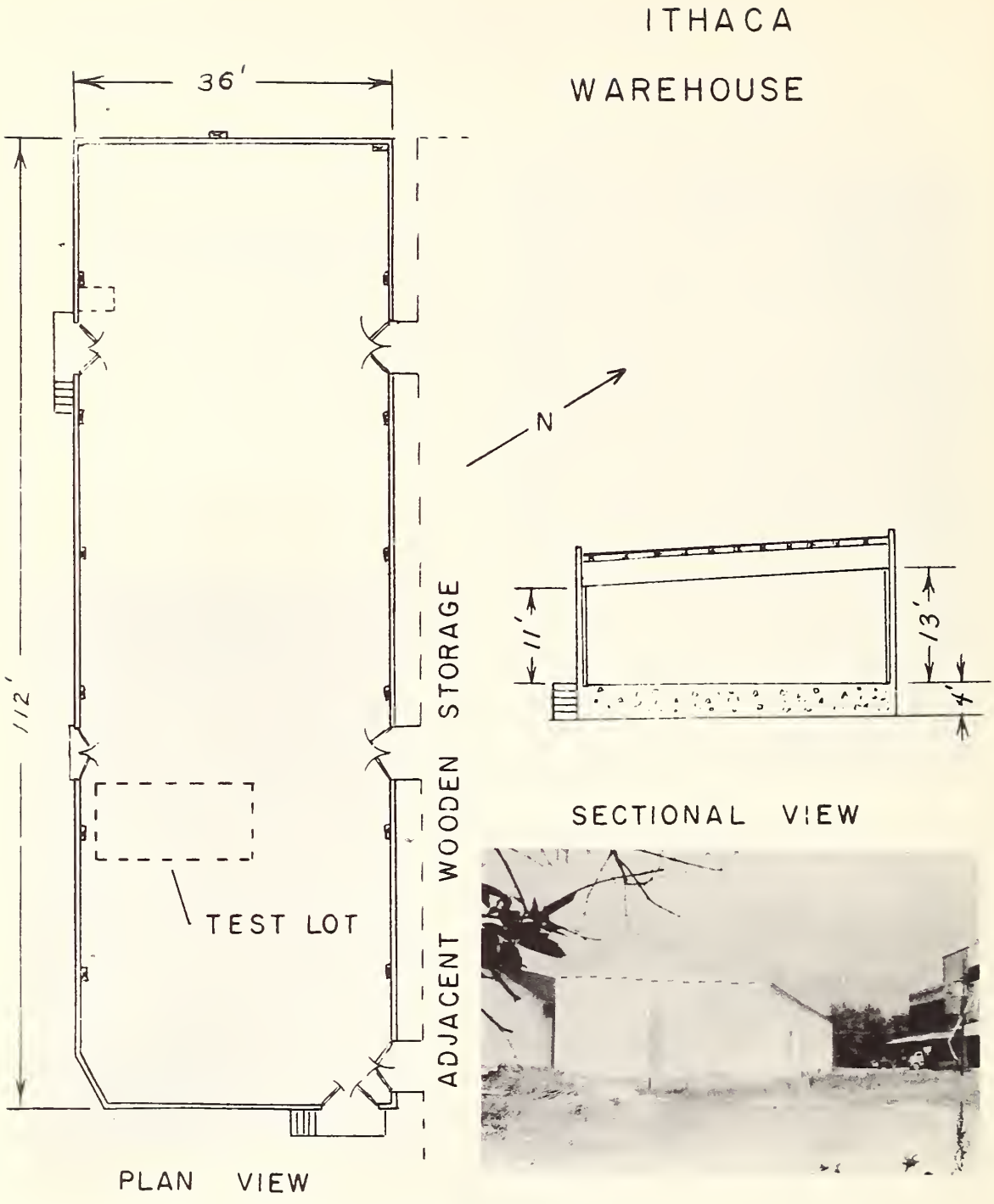
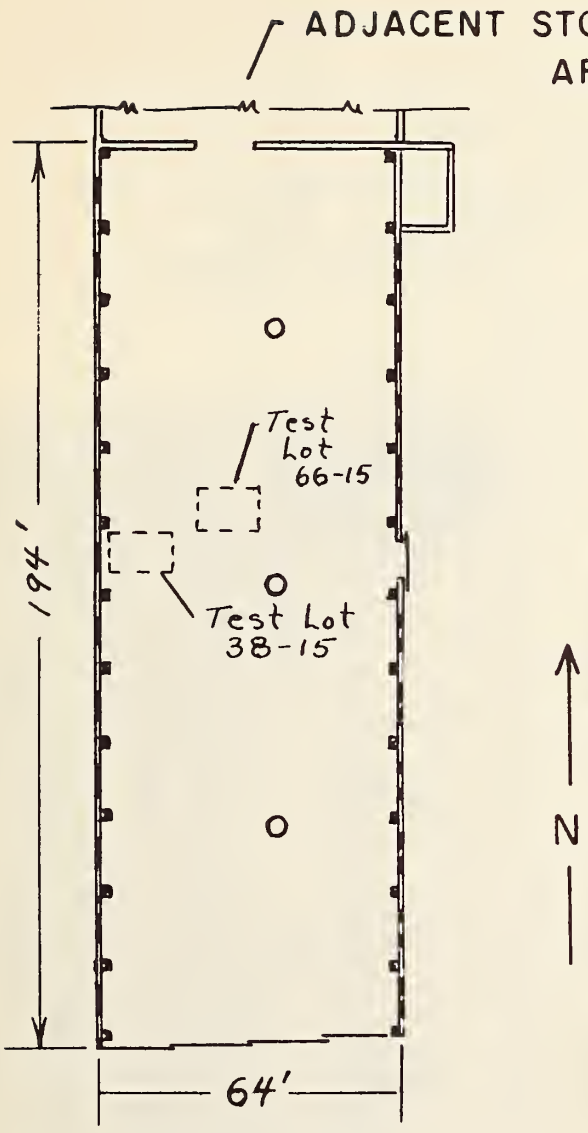


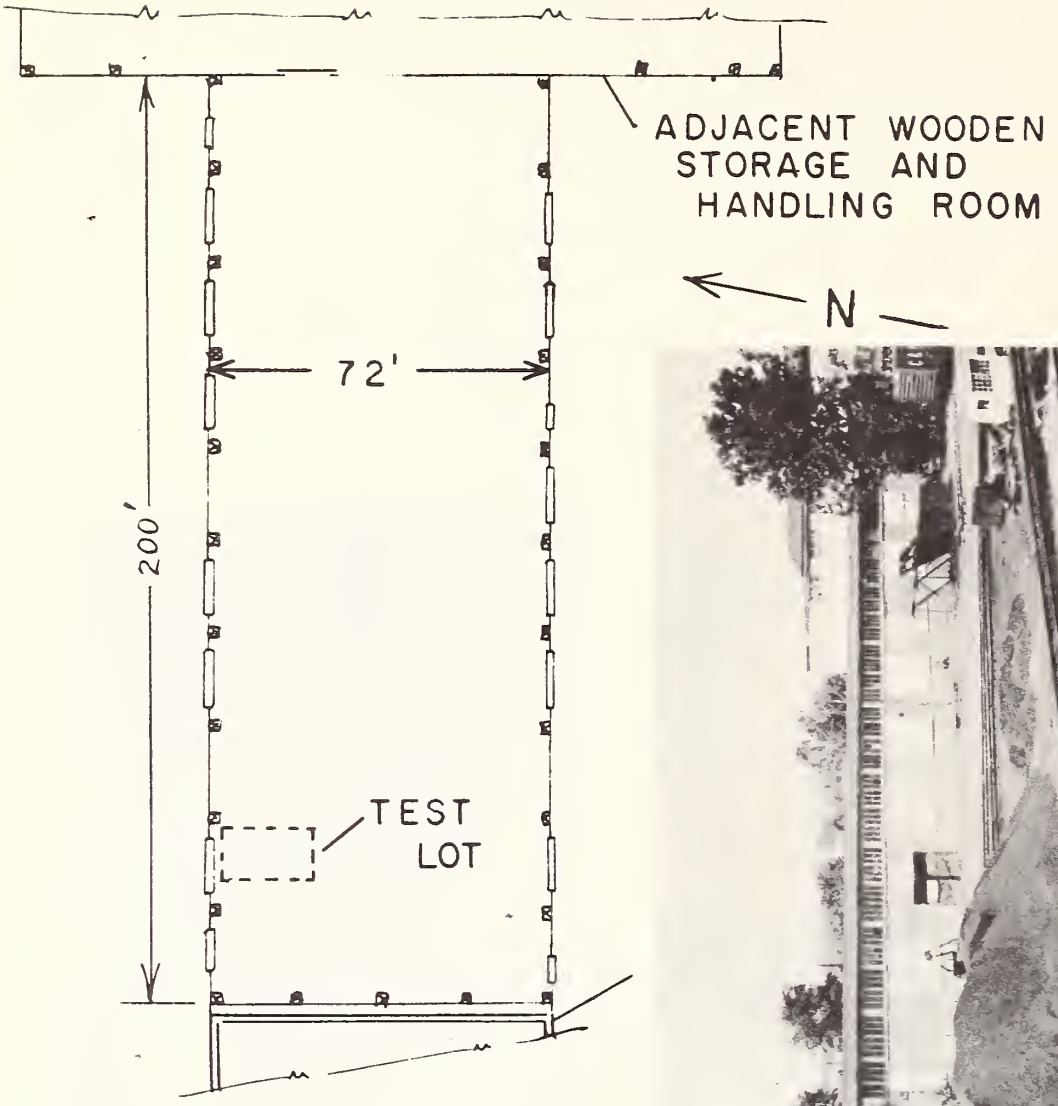
Figure 25. Warehouse C - Ithaca, Michigan

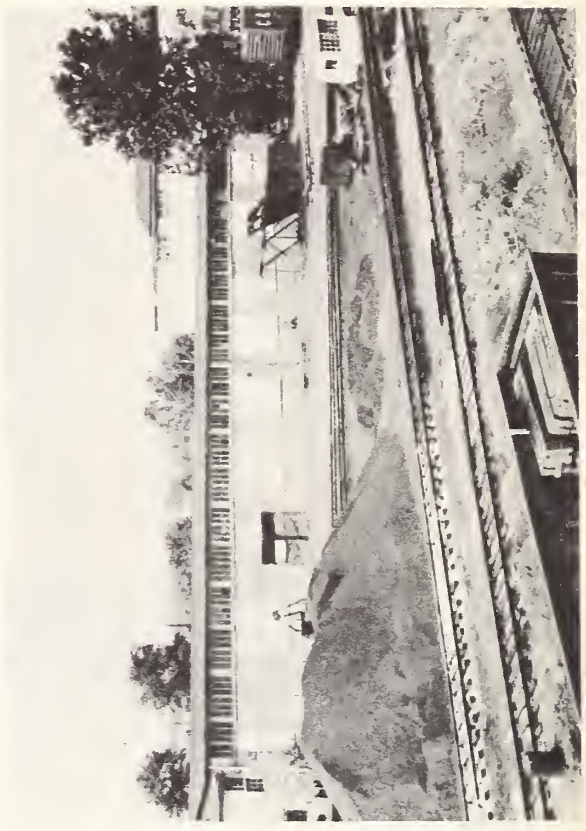


BAY CITY
WAREHOUSE
BLDG NO 15

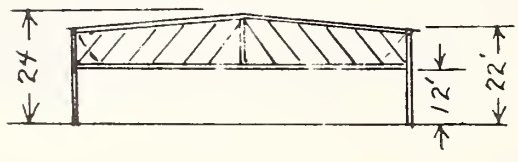
N

Figure 26. Warehouse D - Bay City, Michigan



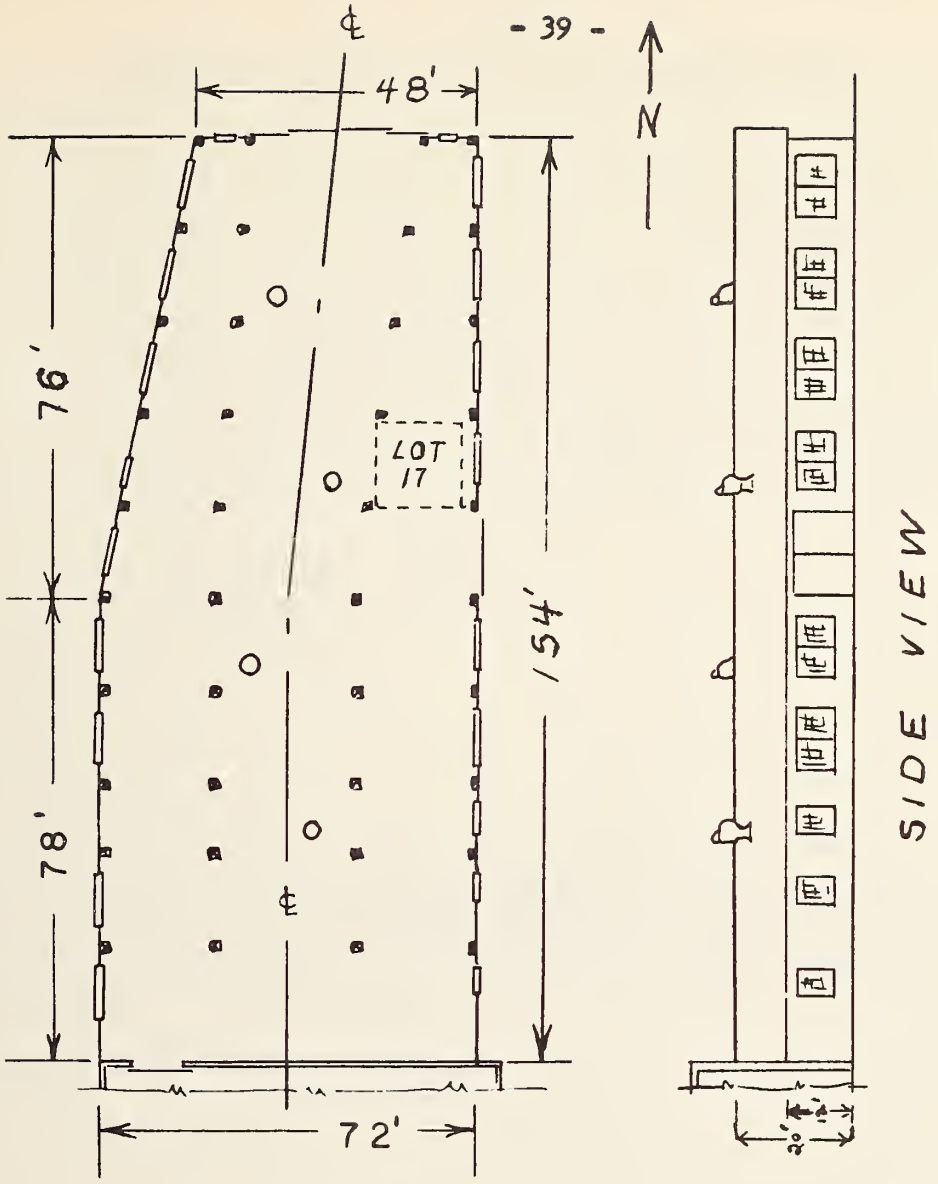


CARROLLTON
WAREHOUSE



SECTIONAL VIEW

Figure 27. Warehouse E - Carrollton, Michigan



BAY CITY
WAREHOUSE
BLDG. NO. 23

Figure 28. Warehouse F - Bay City, Michigan

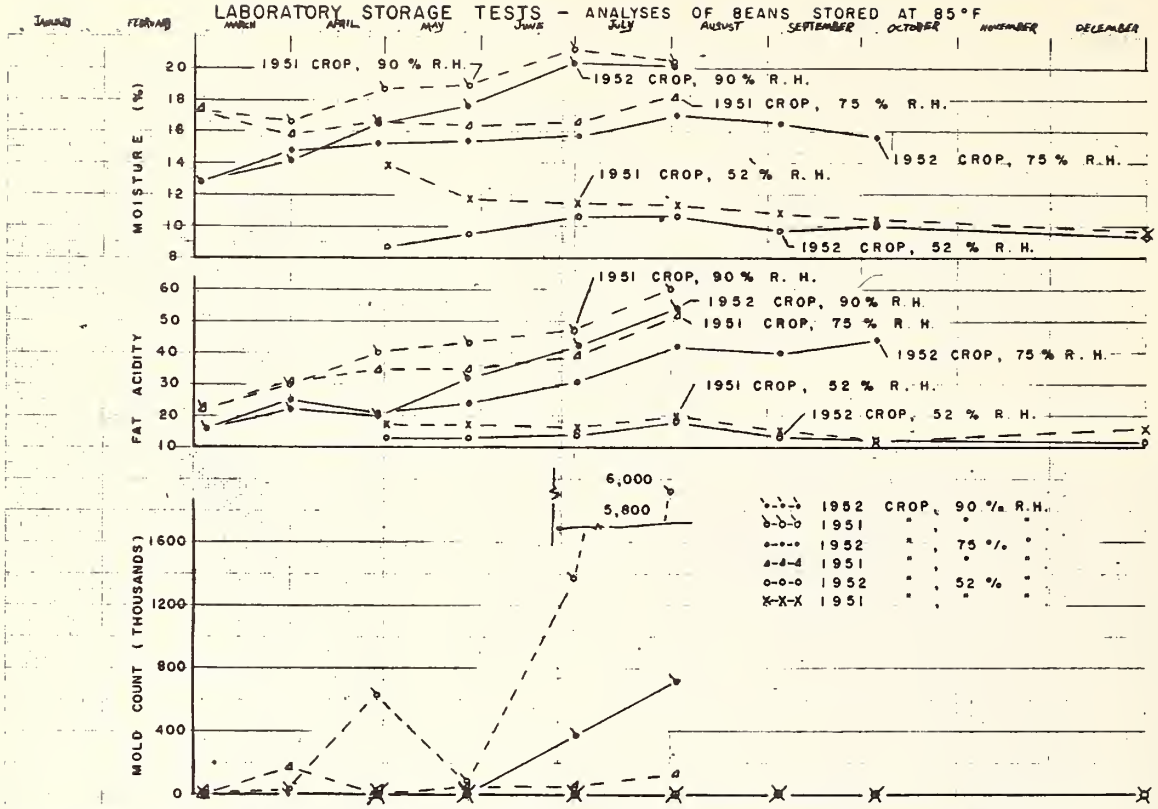

LABORATORY STORAGE TESTS - ANALYSES OF BEANS STORED AT 85° F
JANUARY FEBRUARY MARCH APRIL MAY JUNE JULY AUGUST SEPTEMBER OCTOBER NOVEMBER DECEMBER
MOISTURE (%)
1951 CROP, 90 % R.H.
1952 CROP, 90 % R.H.
1951 CROP, 75 % R.H.
1952 CROP, 75 % R.H.
1951 CROP, 52 % R.H.
1952 CROP, 52 % R.H.
FAT ACIDITY
MOLD COUNT (THOUSANDS)
6,000
5,800
1952 CROP, 90 % R.H.
1951 " " "
1952 " 75 % "
1951 " " "
1952 " 52 % "
1951 " " "

Figure 29.--Test results of 1951 and 1952 pea beans stored at 85° F. and at 52, 75 and 90 percent relative humidity.

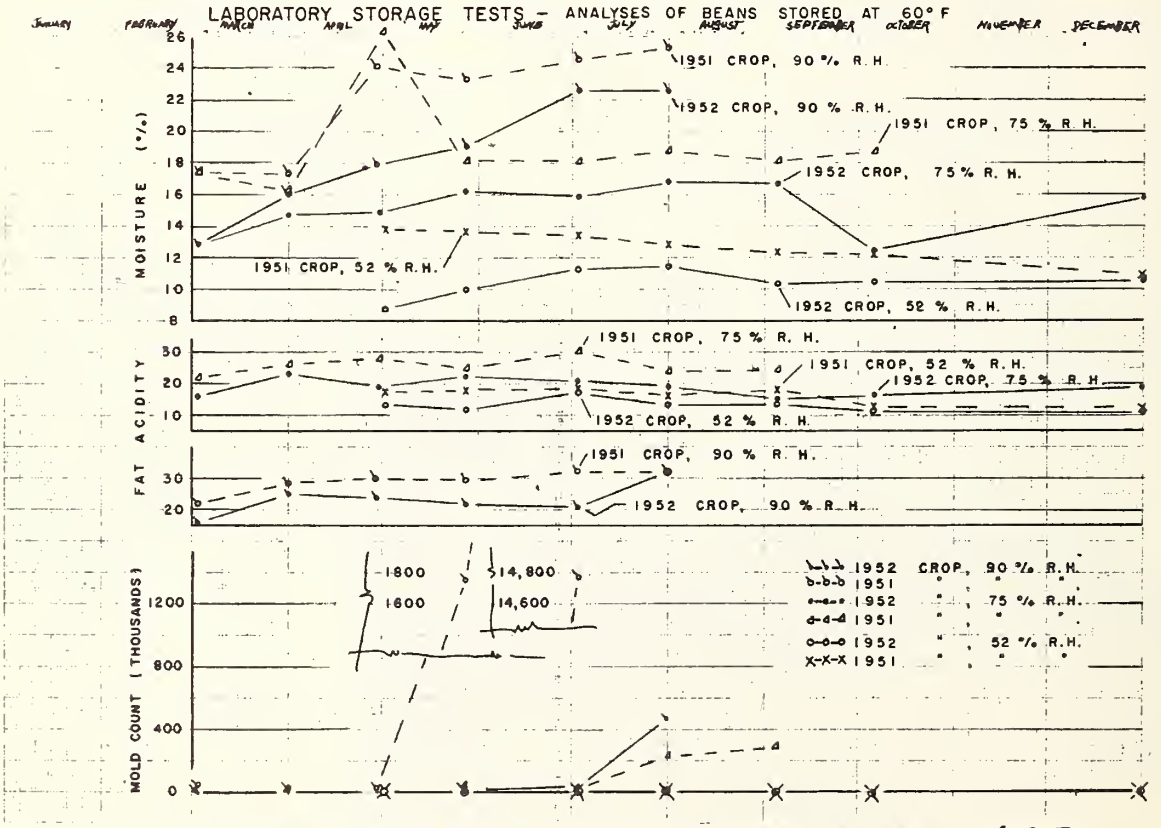

LABORATORY STORAGE TESTS - ANALYSES OF BEANS STORED AT 60° F
JANUARY FEBRUARY MARCH APRIL MAY JUNE JULY AUGUST SEPTEMBER OCTOBER NOVEMBER DECEMBER
MOISTURE (%)
1951 CROP, 90 % R.H.
1952 CROP, 90 % R.H.
1951 CROP, 75 % R.H.
1952 CROP, 75 % R.H.
1951 CROP, 52 % R.H.
1952 CROP, 52 % R.H.
FAT ACIDITY
MOLD COUNT (THOUSANDS)
1800
1600
14,800
14,600
1952 CROP, 90 % R.H.
1951 " " "
1952 " 75 % R.H.
1951 " " "
1952 " 52 % R.H.
1951 " " "

Figure 30.--Test results of 1951 and 1952 pea beans stored at 60° F. and at 52, 75 and 90 percent relative humidity.

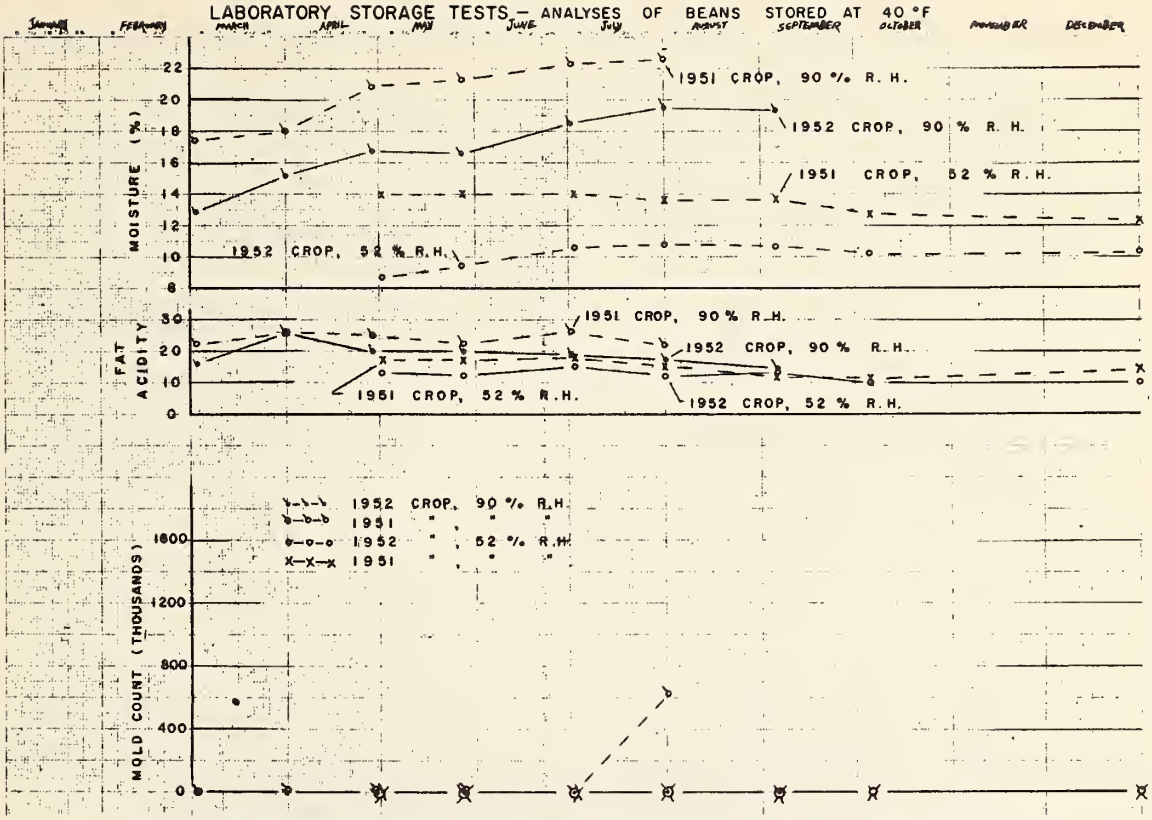

LABORATORY STORAGE TESTS — ANALYSES OF BEANS STORED AT 40 °F
MOISTURE (%)
1951 CROP, 90 % R. H.
1952 CROP, 90 % R. H.
1951 CROP, 52 % R. H.
1952 CROP, 52 % R. H.
FAT ACIDITY
1951 CROP, 90 % R.H.
1952 CROP, 90 % R.H.
1951 CROP, 52 % R.H.
1952 CROP, 52 % R.H.
MOLD COUNT (THOUSANDS)
1952 CROP, 90 % R.H
1951 " " "
1952 " , 52 % R.H
1951 " , " "

Figure 31.--Test results of 1951 and 1952 beans stored at 40° F. and at 52 and 90 percent relative humidity.

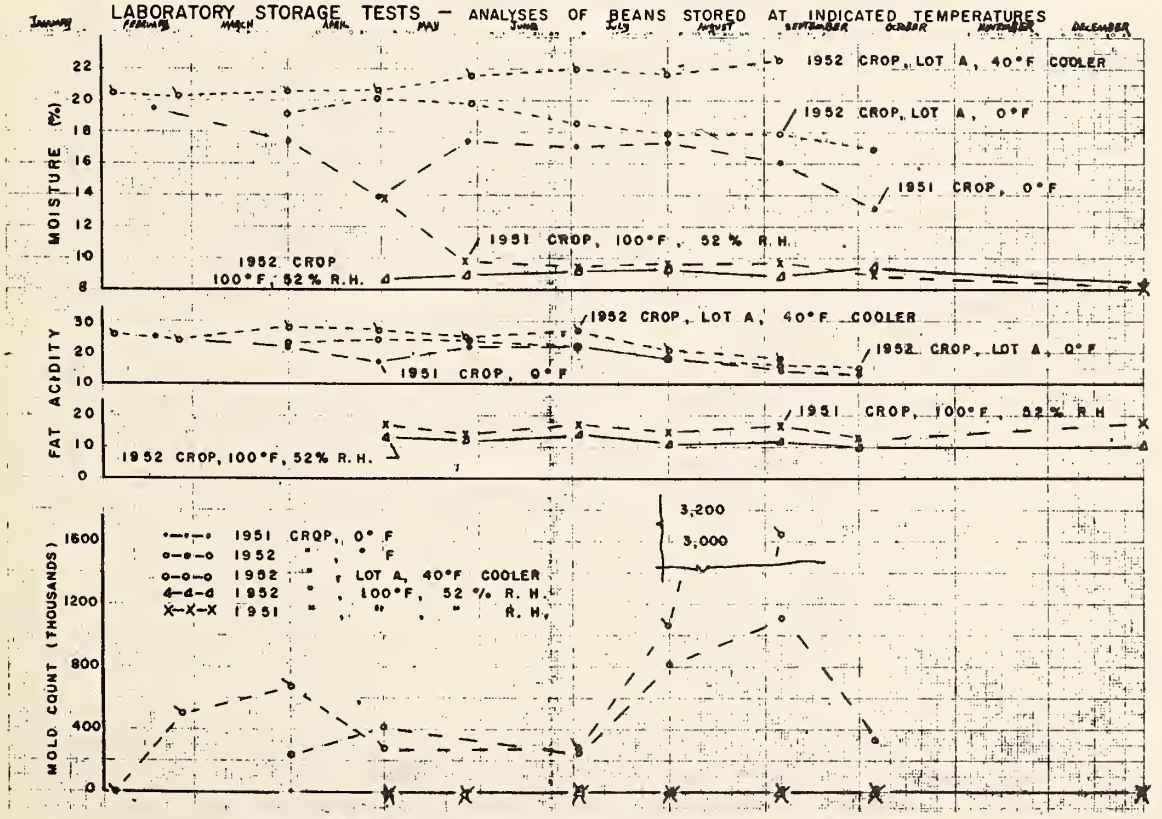

LABORATORY STORAGE TESTS — ANALYSES OF BEANS STORED AT INDICATED TEMPERATURES
MOISTURE (%)
1952 CROP, LOT A, 40°F COOLER
1952 CROP, LOT A, 0°F
1951 CROP, 0°F
1951 CROP, 100°F, 52 % R.H.
1952 CROP 100°F, 52 % R.H.
FAT ACIDITY
1952 CROP, LOT A, 40°F COOLER
1952 CROP, LOT A, 0°F
1951 CROP, 0°F
1951 CROP, 100°F, 52 % R.H
1952 CROP, 100°F, 52% R.H.
MOLD COUNT (THOUSANDS)
1951 CROP, 0° F
1952 " , " F
1952 " , LOT A, 40°F COOLER
1952 " , 100°F, 52 % R. H.
1951 " , " , " R. H.
3,200
3,000

Figure 32.--Test results of various lots of beans stored at the temperatures indicated. Text of the report gives details.

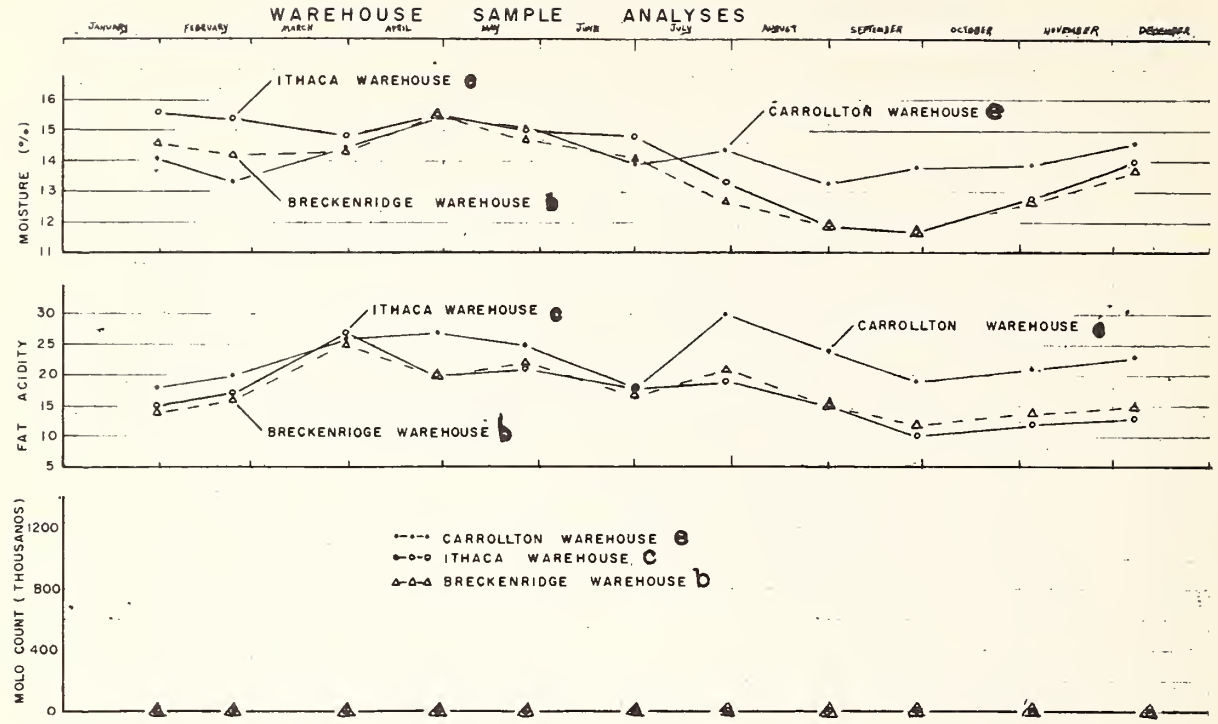


Figure 33.--Fat acidity and moisture relationship by months 1953 for Ithaca, Carrollton, and Breckenridge Warehouses.

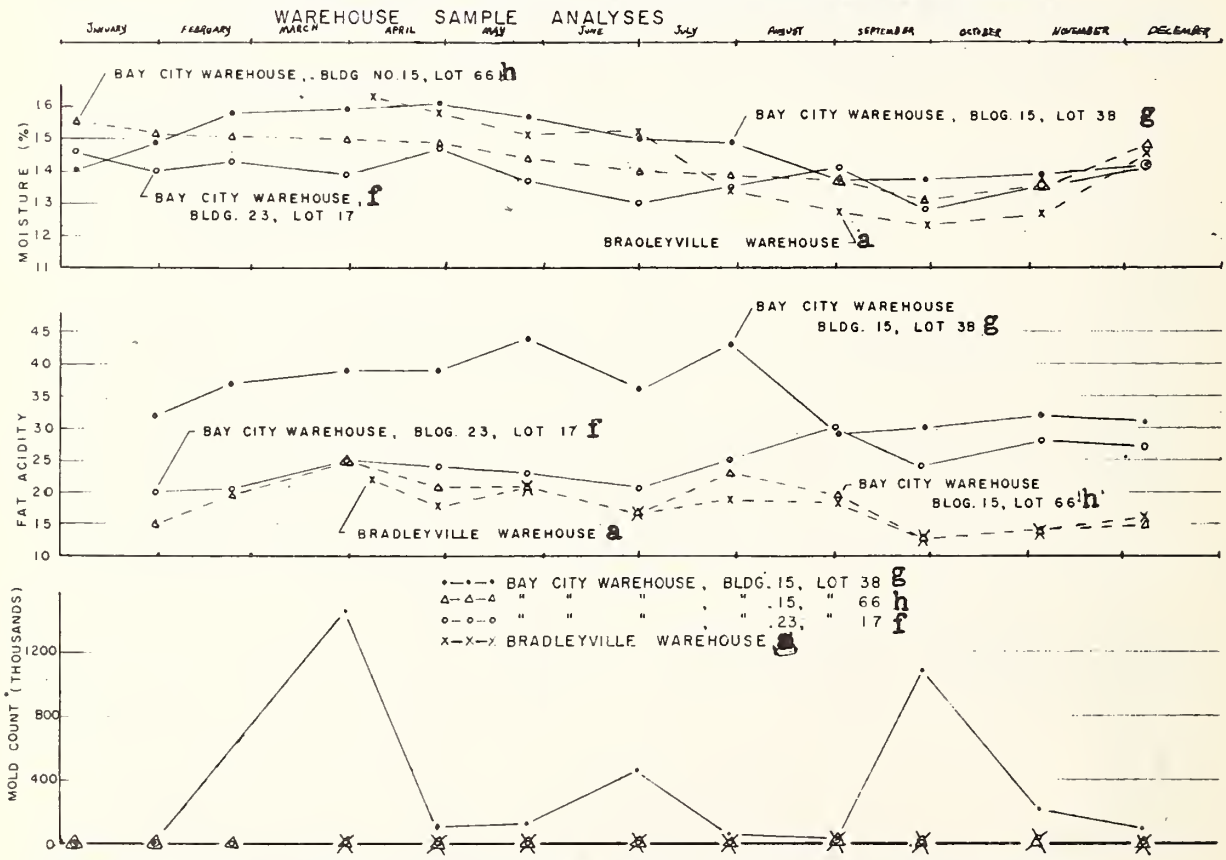


Figure 34--Fat acidity and moisture relationship by months 1953 for Bay City Warehouses, Bldg. No.15, lots 66 and 38 and Bldg. No. 23, lot 17, and Bradleyville Warehouse.

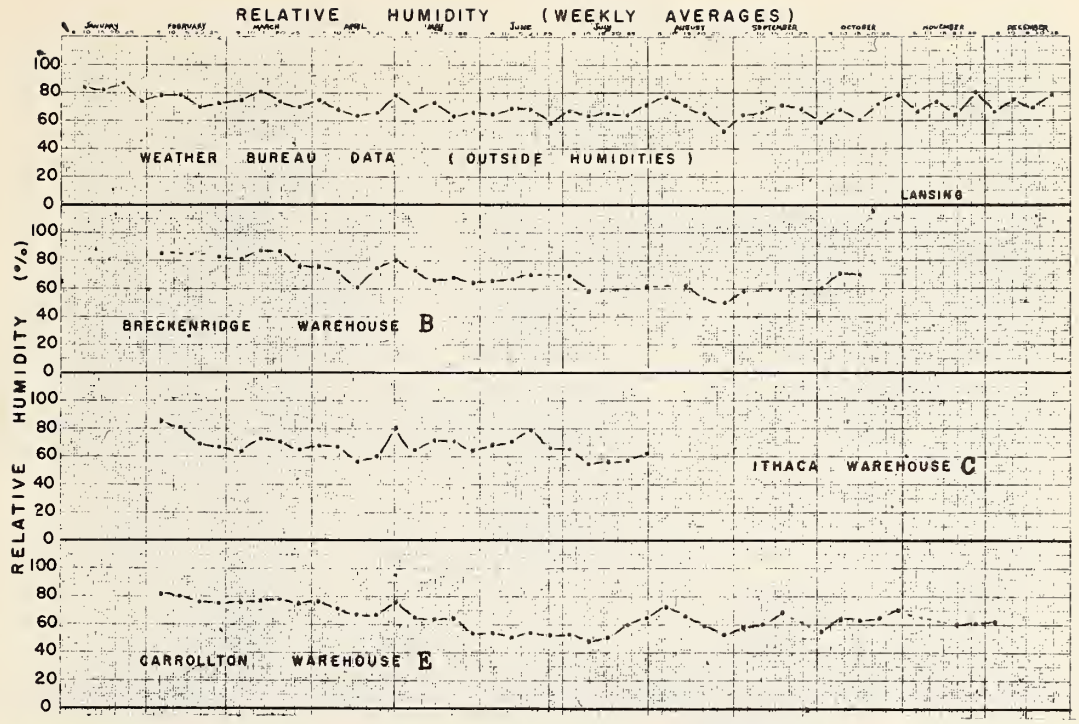


Figure 35.--Relative humidity in bean warehouse at Breckenridge, Ithaca and Carrollton, Mich., compared to official outside relative humidity at Lansing, Michigan, for calendar year 1953.

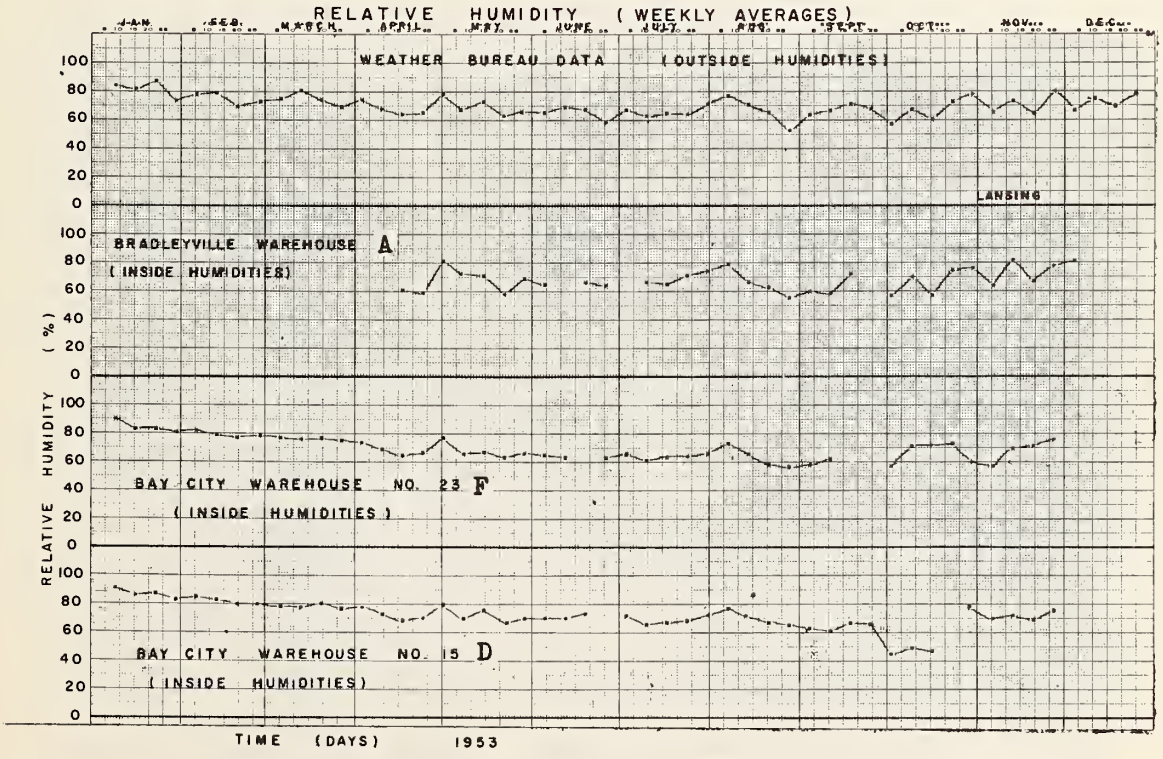


Figure 36.--Relative humidity in bean warehouses No. 23 and No. 15 at Bay City, Michigan.

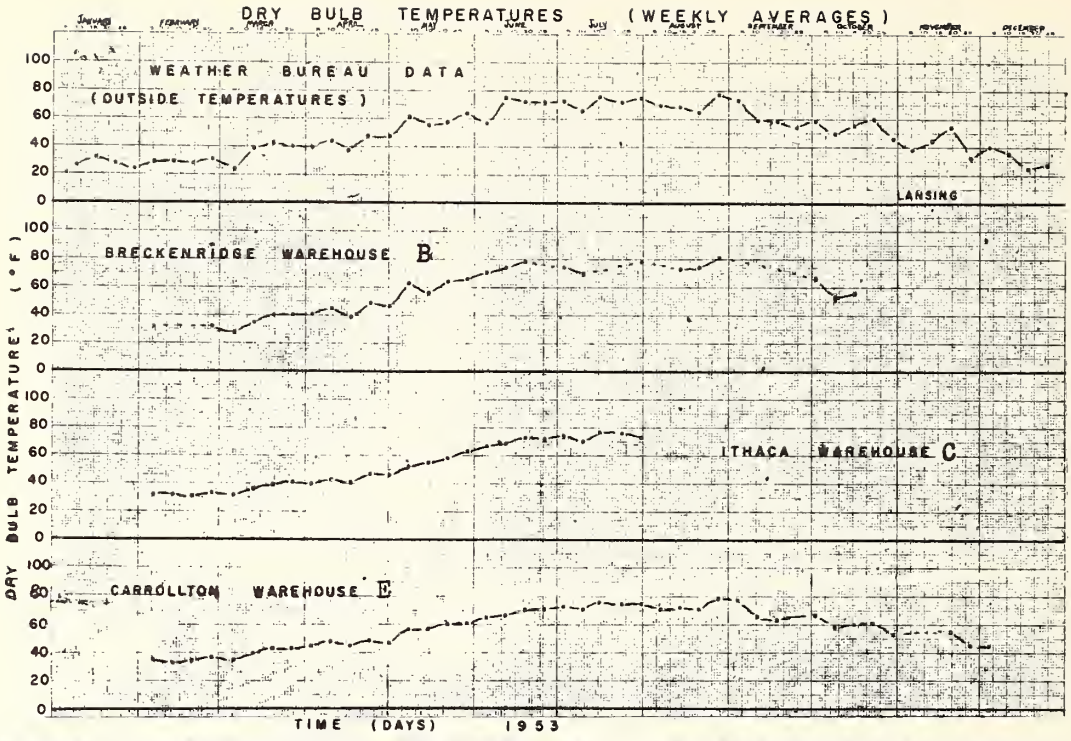


Figure 37.--Temperatures (weekly averages) - inside warehouses at Breckenridge, Ithaca and Carrollton, Mich., compared with official outside temperatures at Lansing, for calendar year 1953.

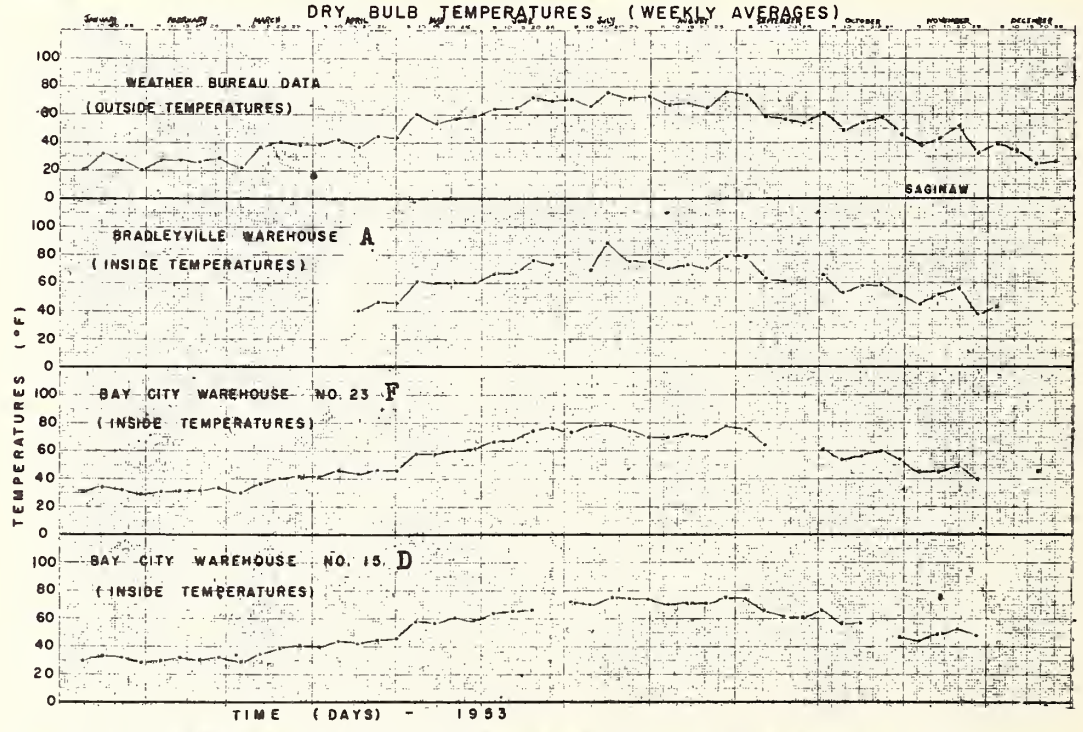


Figure 38.--Temperatures (weekly averages) - inside warehouses at Bradleyville and Bay City, Mich., compared with official temperatures at Saginaw, for calendar year 1953.

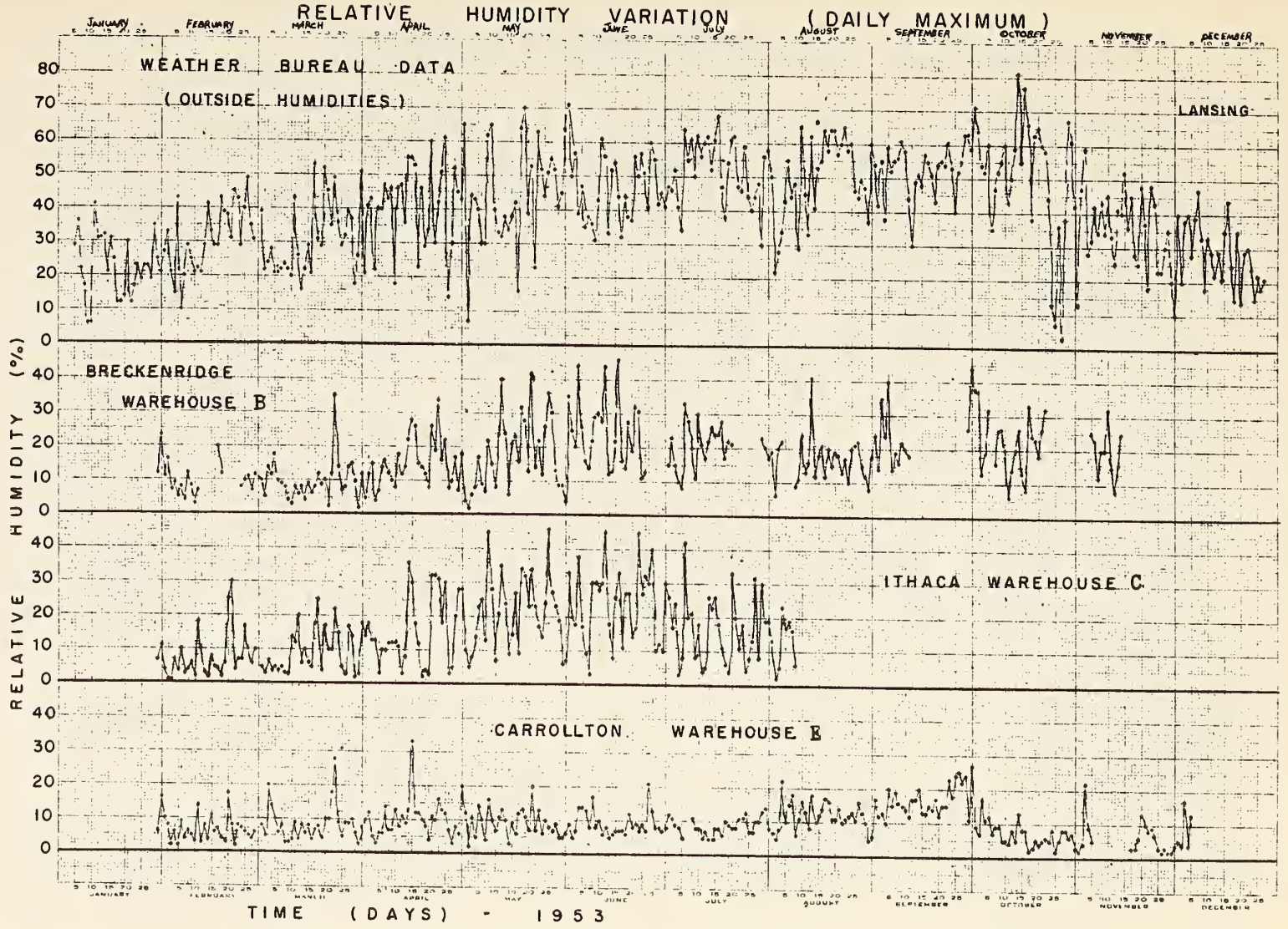


Figure 39.--Relative humidity variation in warehouses at Breckenridge, Ithaca and Carrollton, Mich., compared with official outside humidity at Lansing, calendar year 1953.

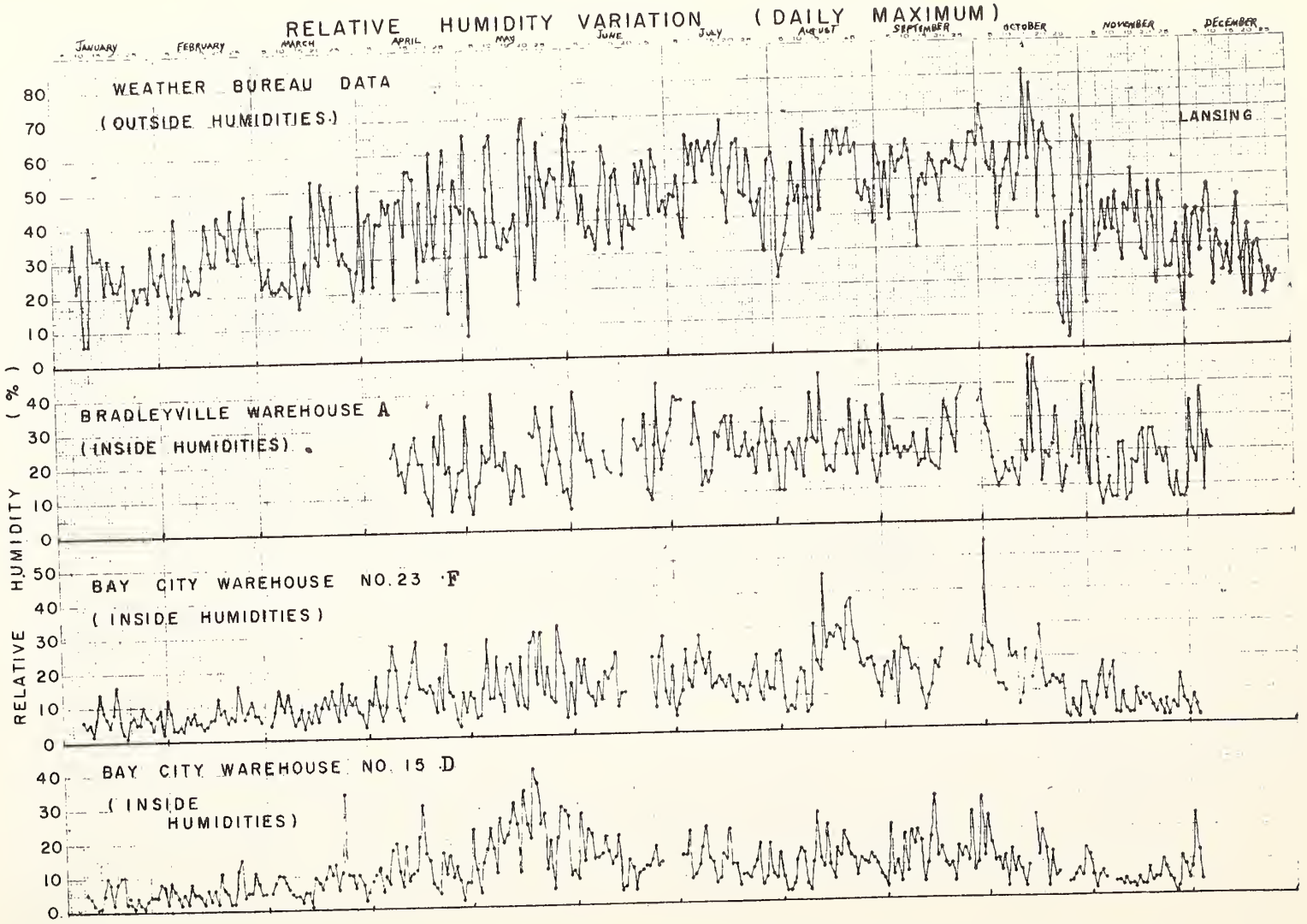


Figure 40.--Relative humidity daily maximum with inside and outside comparisons at Bradleyville and Bay City Warehouses.

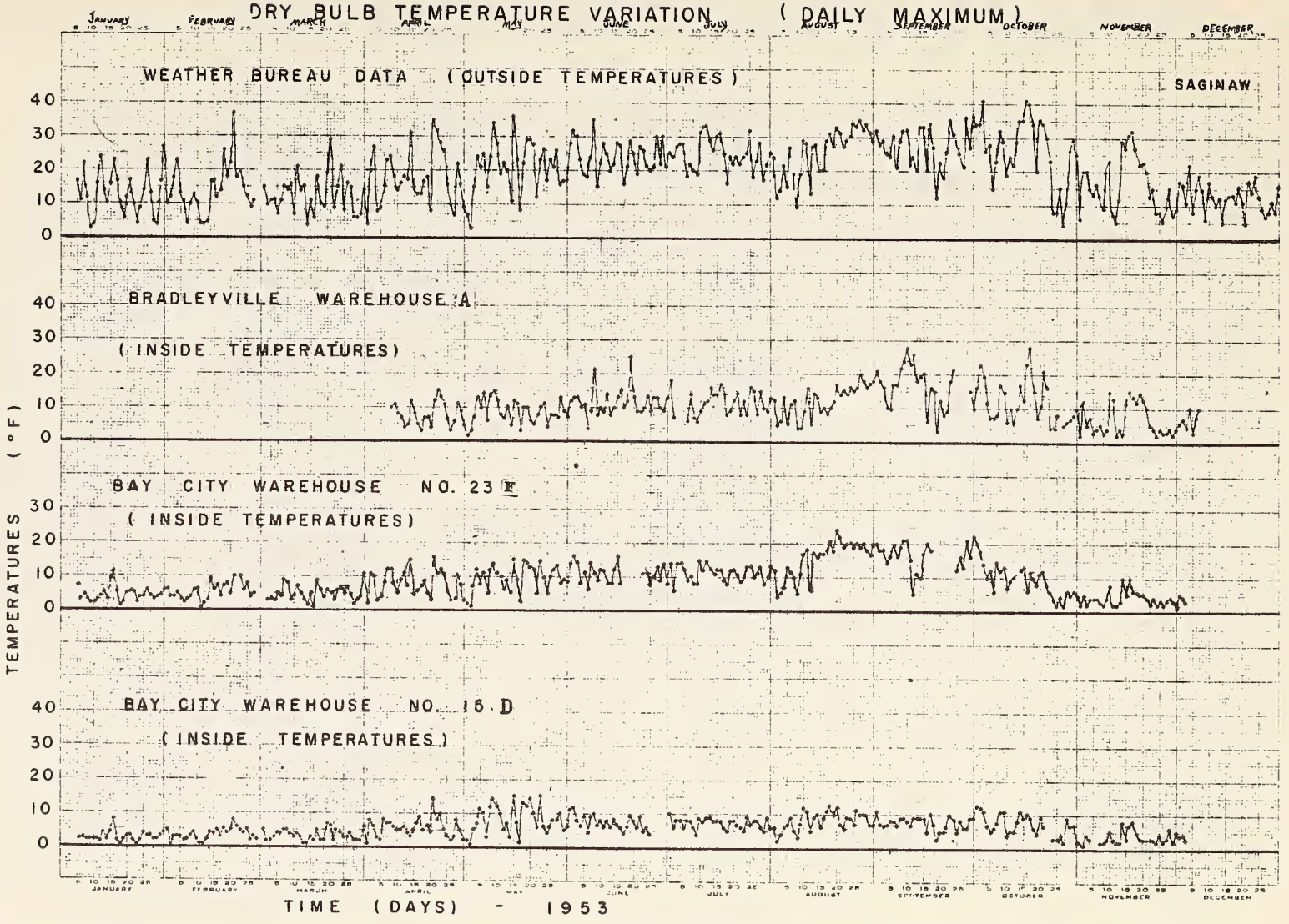


Figure 41.--Temperature variation in warehouses at Bay City and Bradleyville, Mich., compared with the official outside temperature at Saginaw for the calendar year 1953.

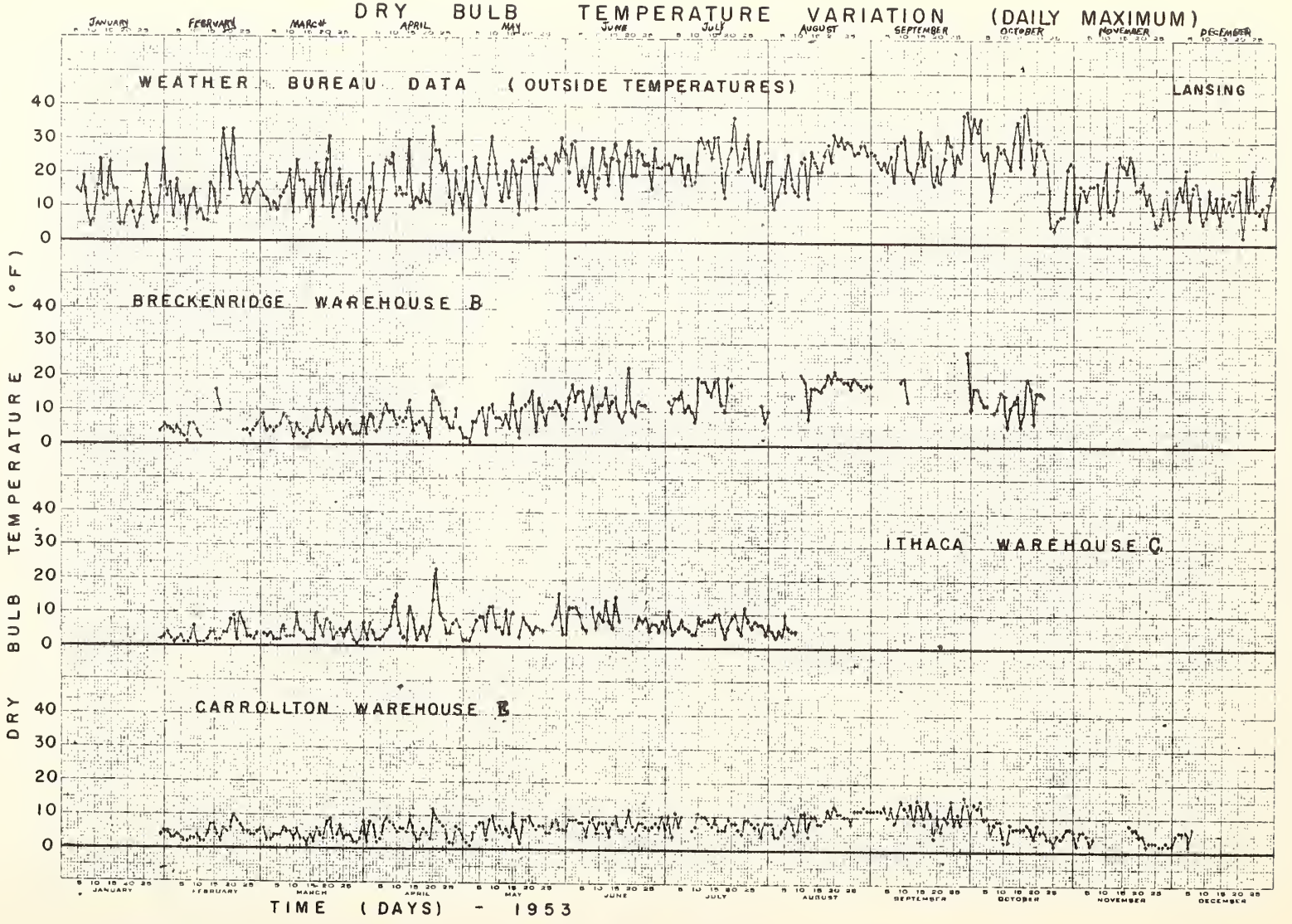
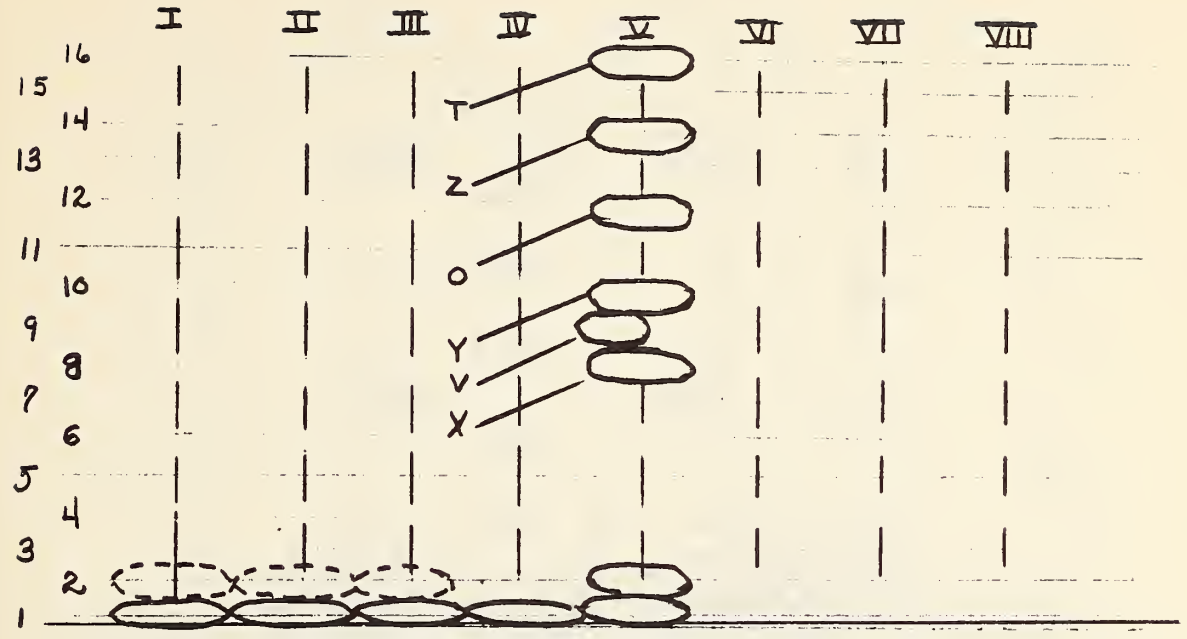
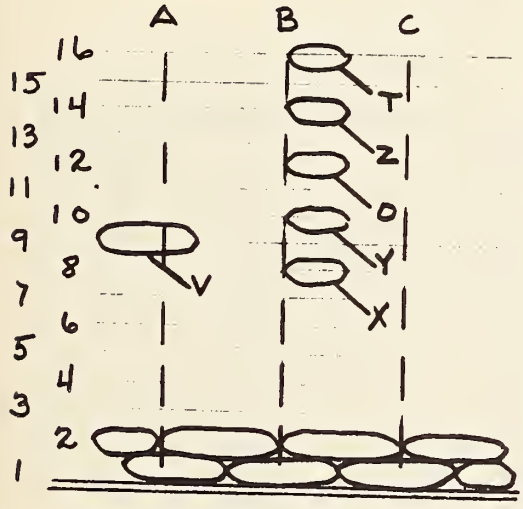


Figure 42.--Temperature variation in warehouses at Breckenridge, Ithaca and Carrollton, Michigan compared with the official outside temperature at Lansing for the calendar year 1953.



Sectional View of Right Side of Lot



Front Sectional View

Analysis Date **

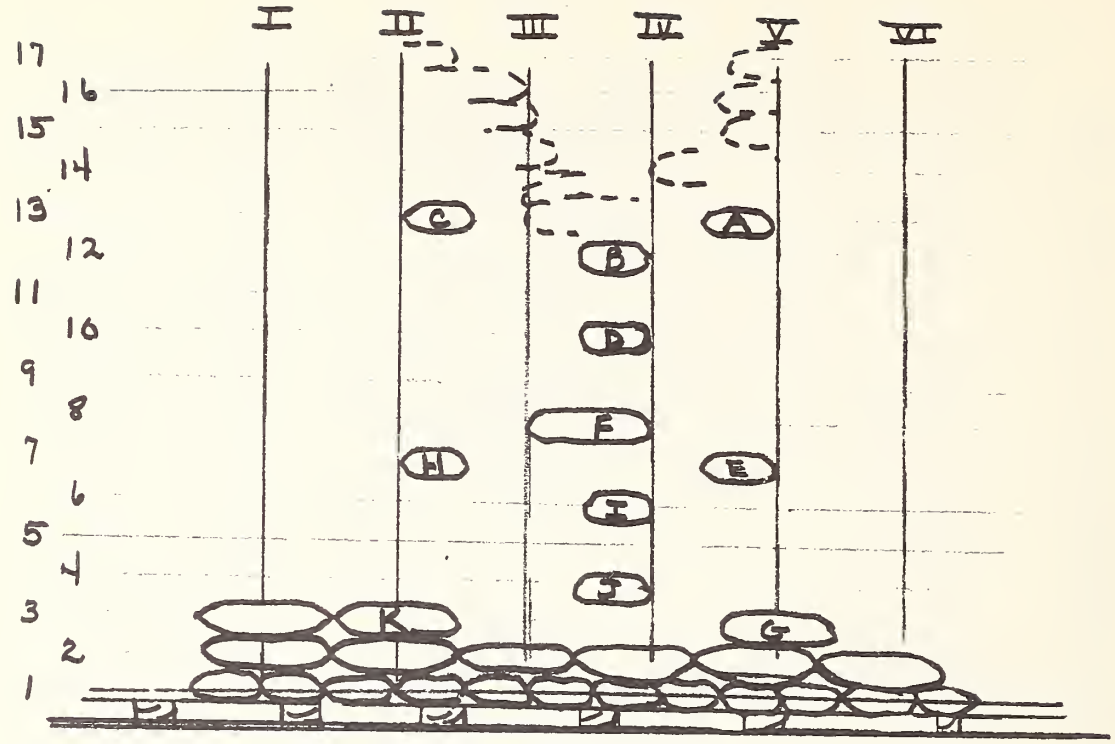
Sample Number	Position	Moisture %	Fat Acidity	Mold
91-S	X	16.2	17	40
92-S	Y	16.2	18	40
93-S	O	16	16	40
94-S	Z	15.8	17	40
95-S	T	14.1	15	16
96-S	V	15.9	18	56
97-S	Random*	14.5	17	4

* random sample from edges of lot typical of normal sampling procedure.

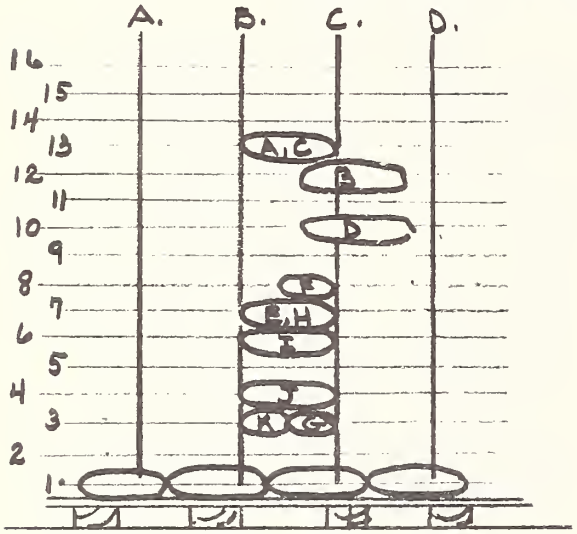
** Mischilite beans stored 10-5-52. Beans are from no particular grower. No. 1 Michigan beans.

Figure 43.--SAMPLING OF CARLOAD OF MICHIGAN PEA BEANS AT WAREHOUSE C, ITHACA, MICHIGAN

JUNE 12, 1953



Sectional View of Left Side of Lot



Front Sectional View

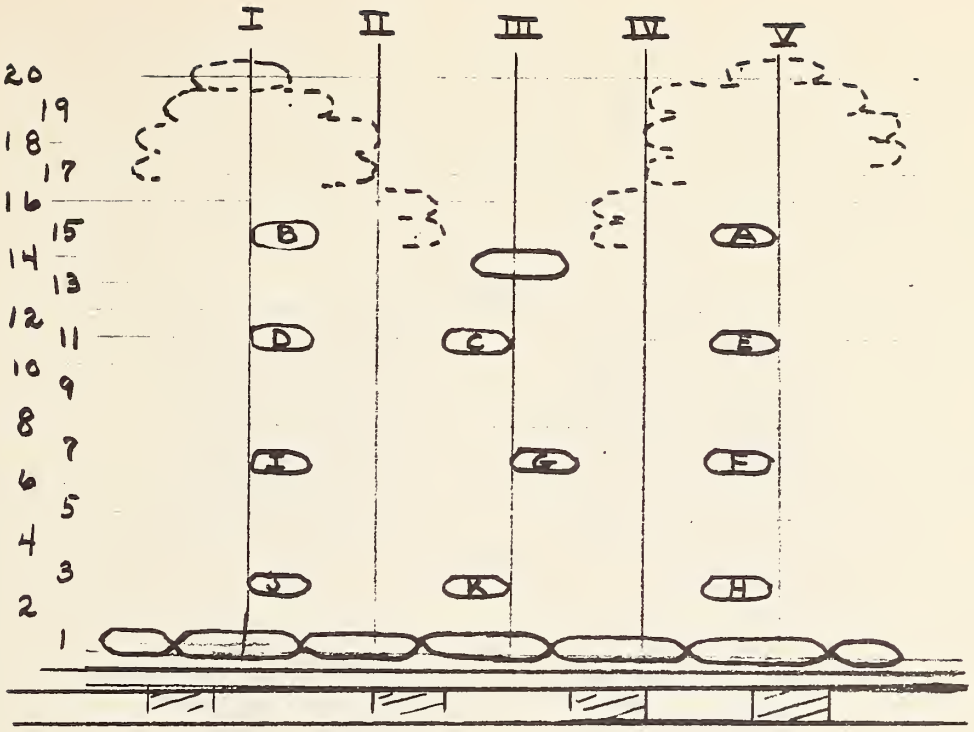
Analysis Data

Sample Number	Position	Moisture %	Fat Acidity	Mold
154-S	A	16.5	32	
155-S	X*	12.6	24	
156-S	B	16.9	36	
157-S	C	16.6	39	
158	D	17.7	34	
159	E	17.1	30	
160	F	18.4	39	
161	G	18.2	35	
162	H	17.6	31	
163	I	18.4	34	
164	J	17.8	30	
165	K	17.9	31	

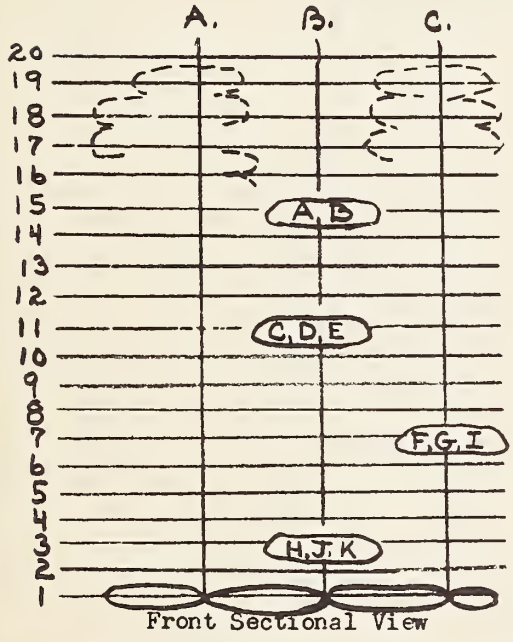
* random sample from edges of lot typical of normal sampling procedure.

Figure 44. SAMPLING OF CARLOAD LOT OF MICHIGAN PEA BEANS AT BAY CITY, MICHIGAN

Building 23, Lot 17 August 7, 1953



Sectional view from Left Side of Lot



Front Sectional View

Analysis Data

Sample Number	Position	Moisture	Fat Acidity	Mold
172-S	X*	13.3	24	
173-S	A	16.6	28	
174-S	B	15.9	28	
175-S	C	16.1	28	
176	D	16.4	25	
177	E	16.2	24	
178	F	16.3	25	
179	G	17.2	25	
180	H	14.9	21	
181	I	16.6	24	
182	J	15.4	20	
183	K	16.6	23	

* random sample from edges of lot.

Figure 45. SAMPLING OF CARLOAD LOT OF MICHIGAN PEA BEANS AT CARROLLTON.

Bond, Lot 33 September 1, 1953

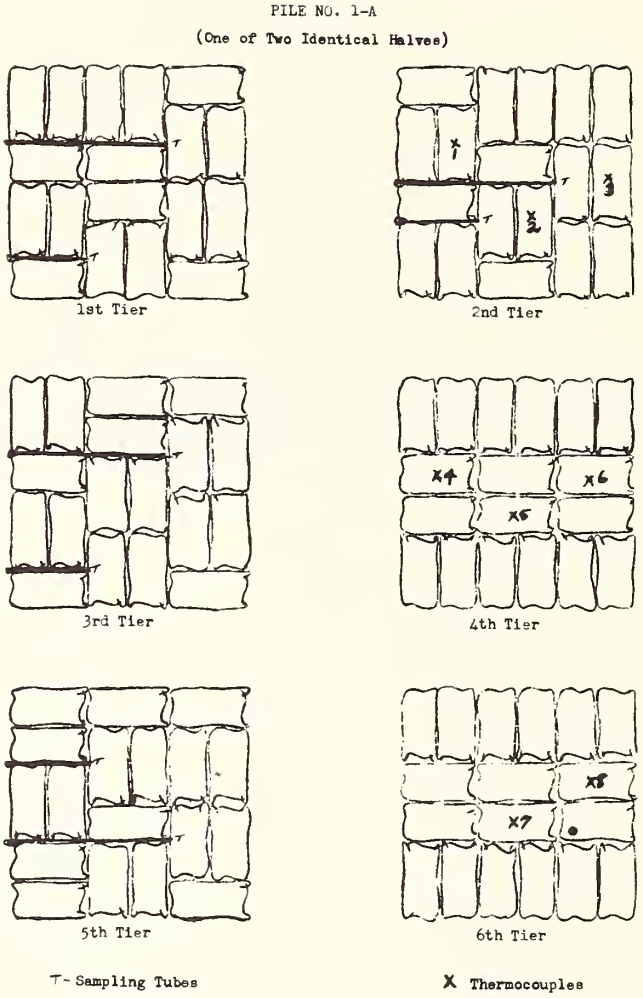


Figure 46.--Location of sampling tubes (T) and thermocouples (X) in check pile No. 1-A, Ash Grove, Indiana.

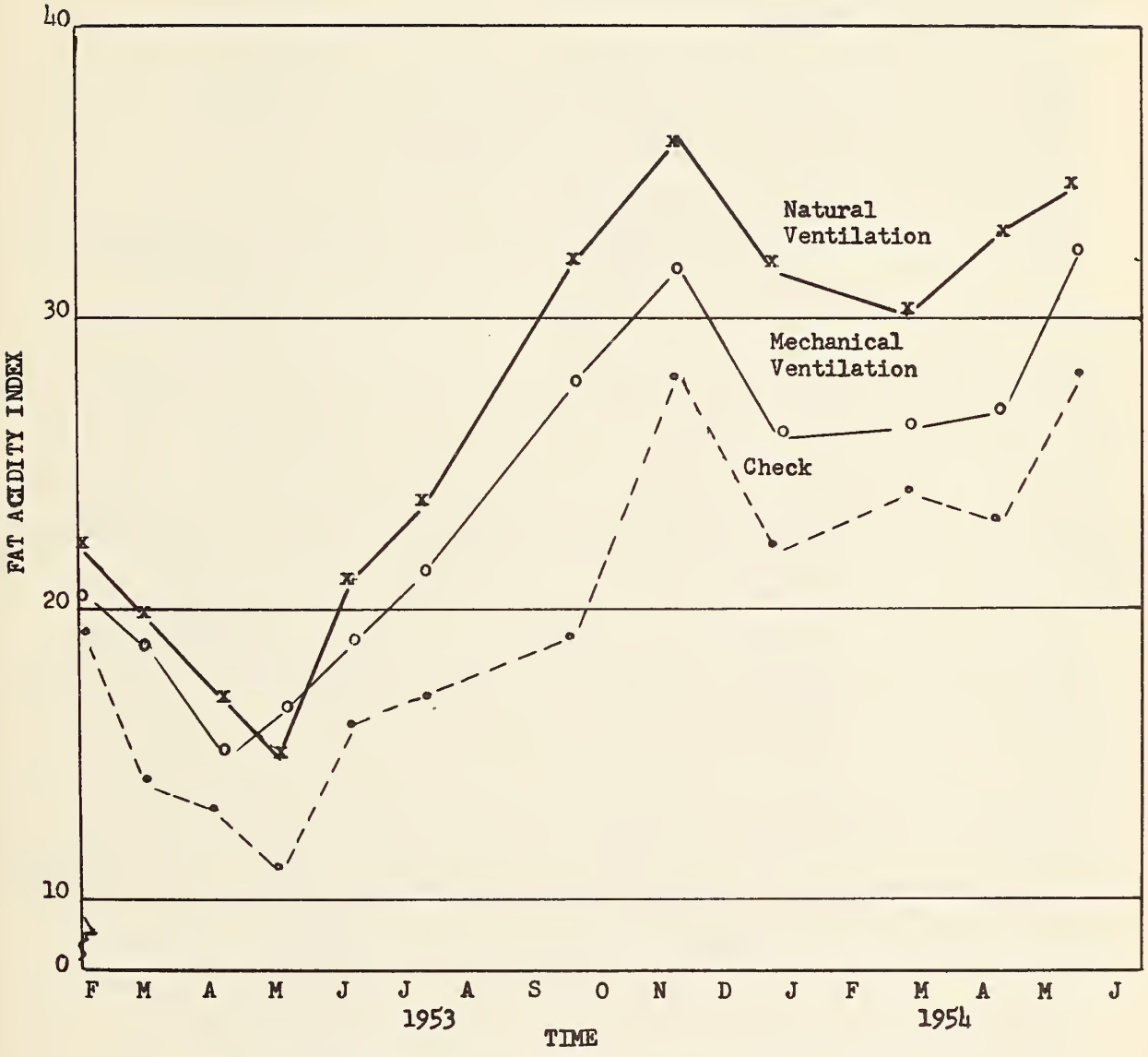


Figure 47.-Changes of fat acidity in beans stored at Ash Grove, Indiana

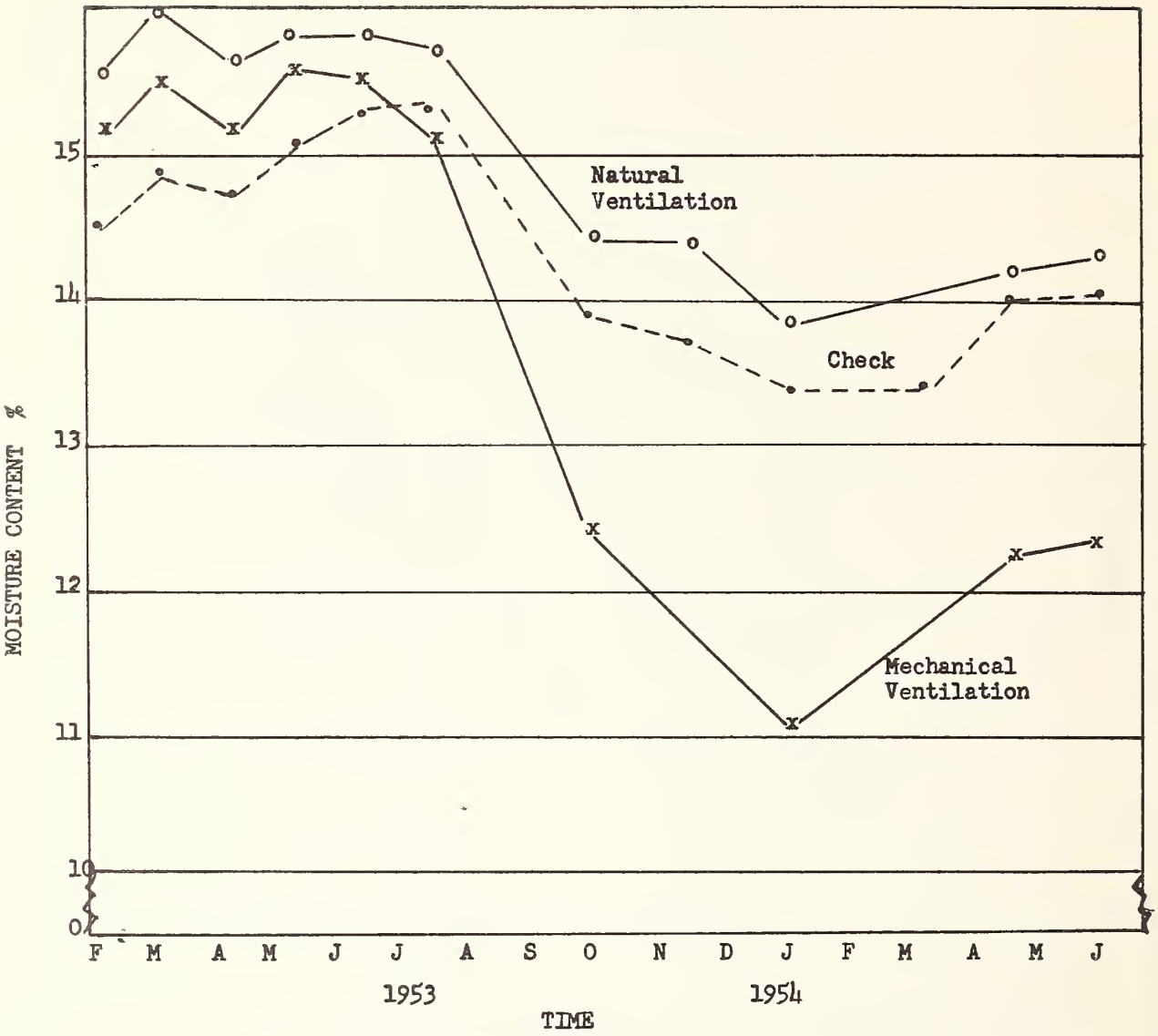


Figure 48.-Comparison of moisture content of beans stored at Ash Grove, Indiana

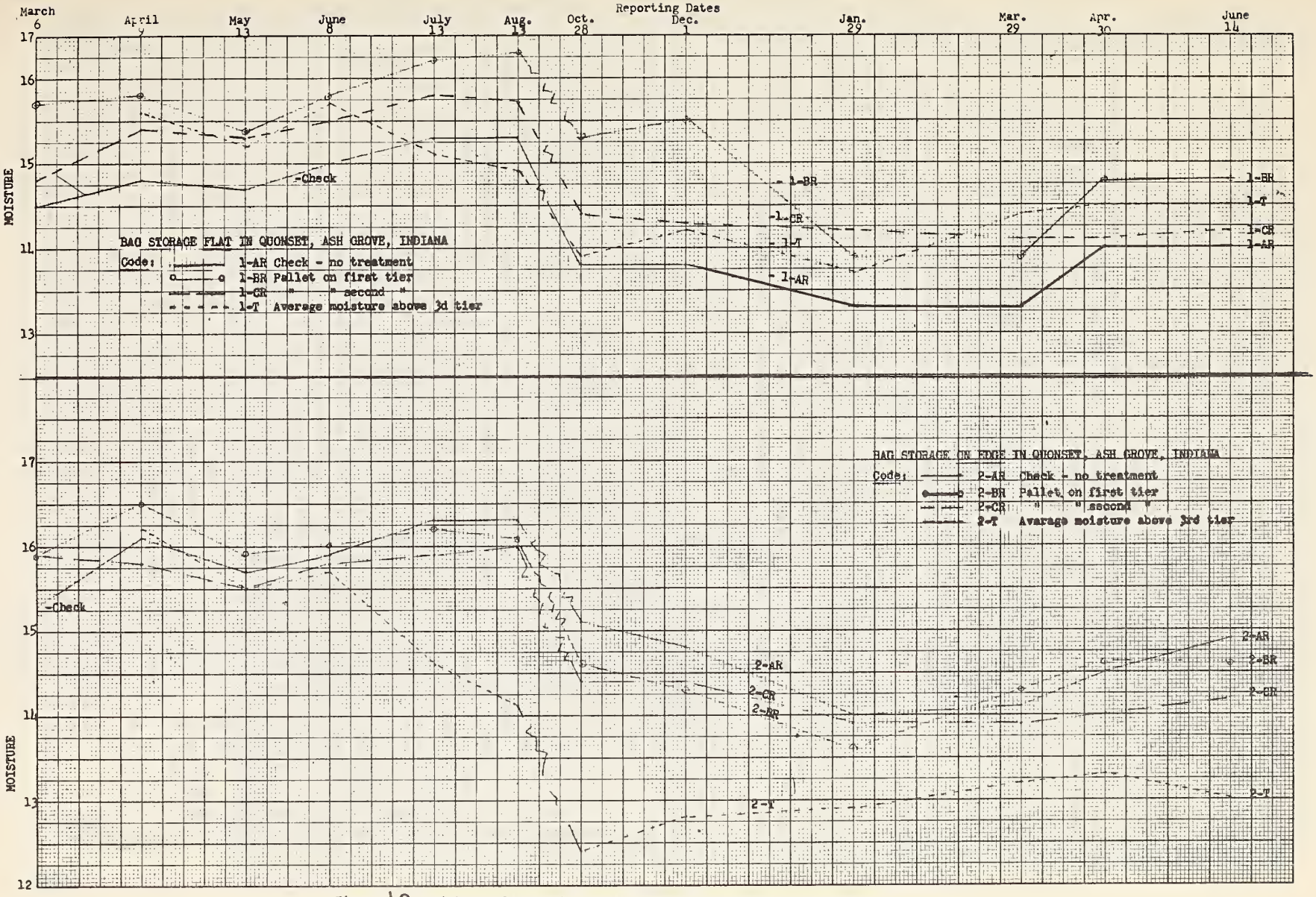


Figure 49--Moisture Relationships of Bags Stacked Flat (normal) or on Edge.

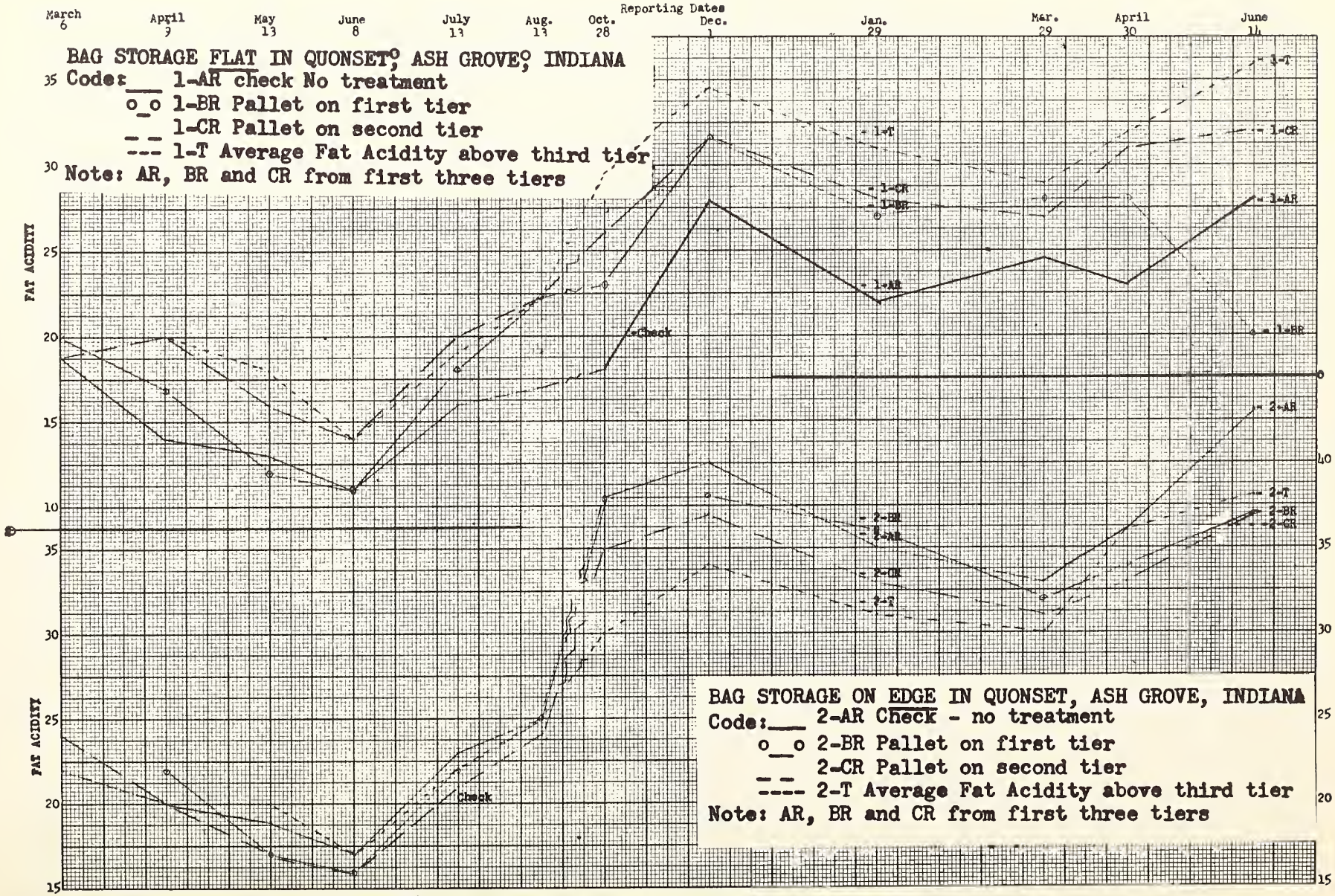


Figure 50-Fat Acidity Relationship of Bags Stacked Flat, Normal or on Edge

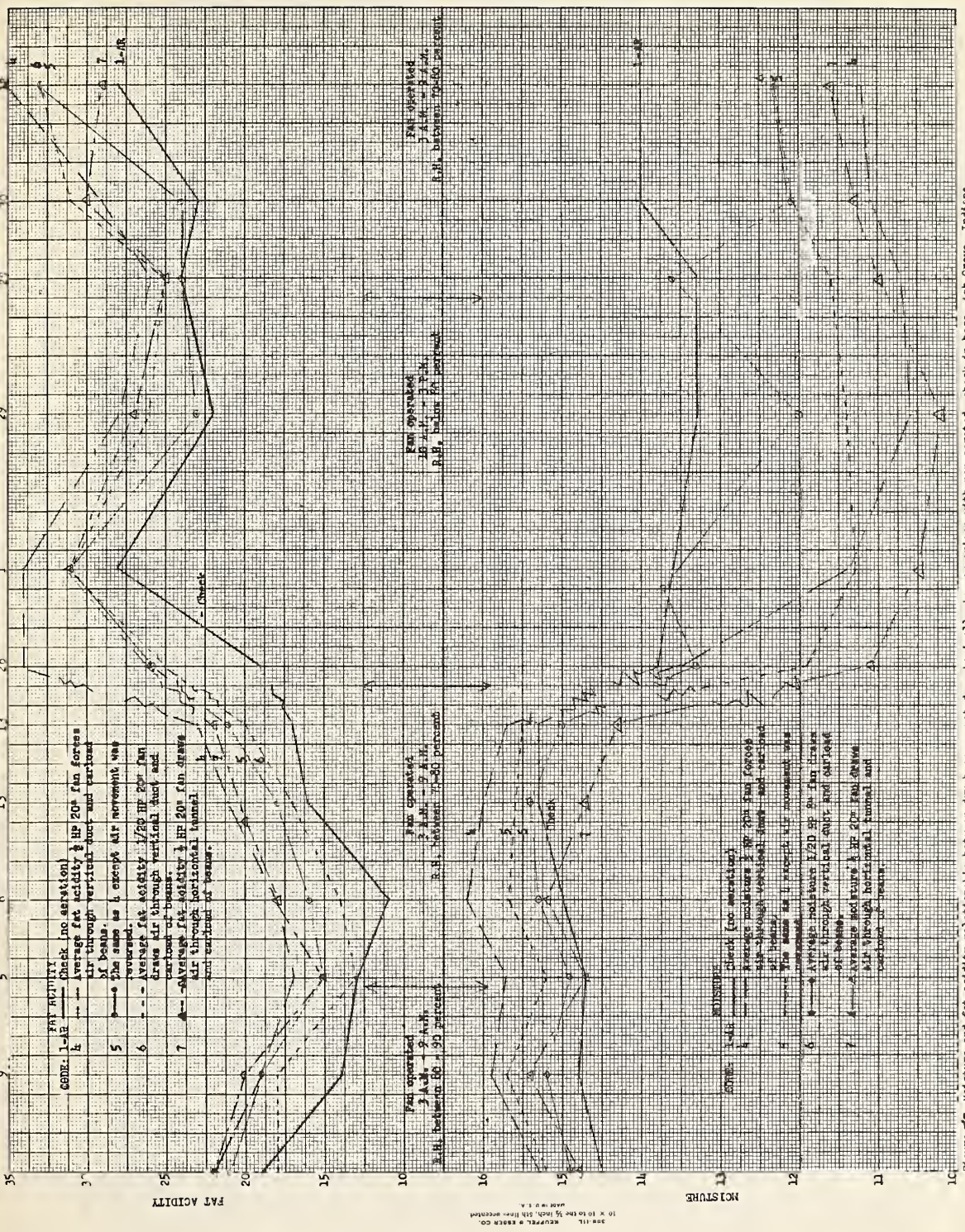


Figure 51 -Moisture and fat acidity relationship between dry beans aerated mechanically in comparison with non-aerated check in bags, Ash Grove, Indiana

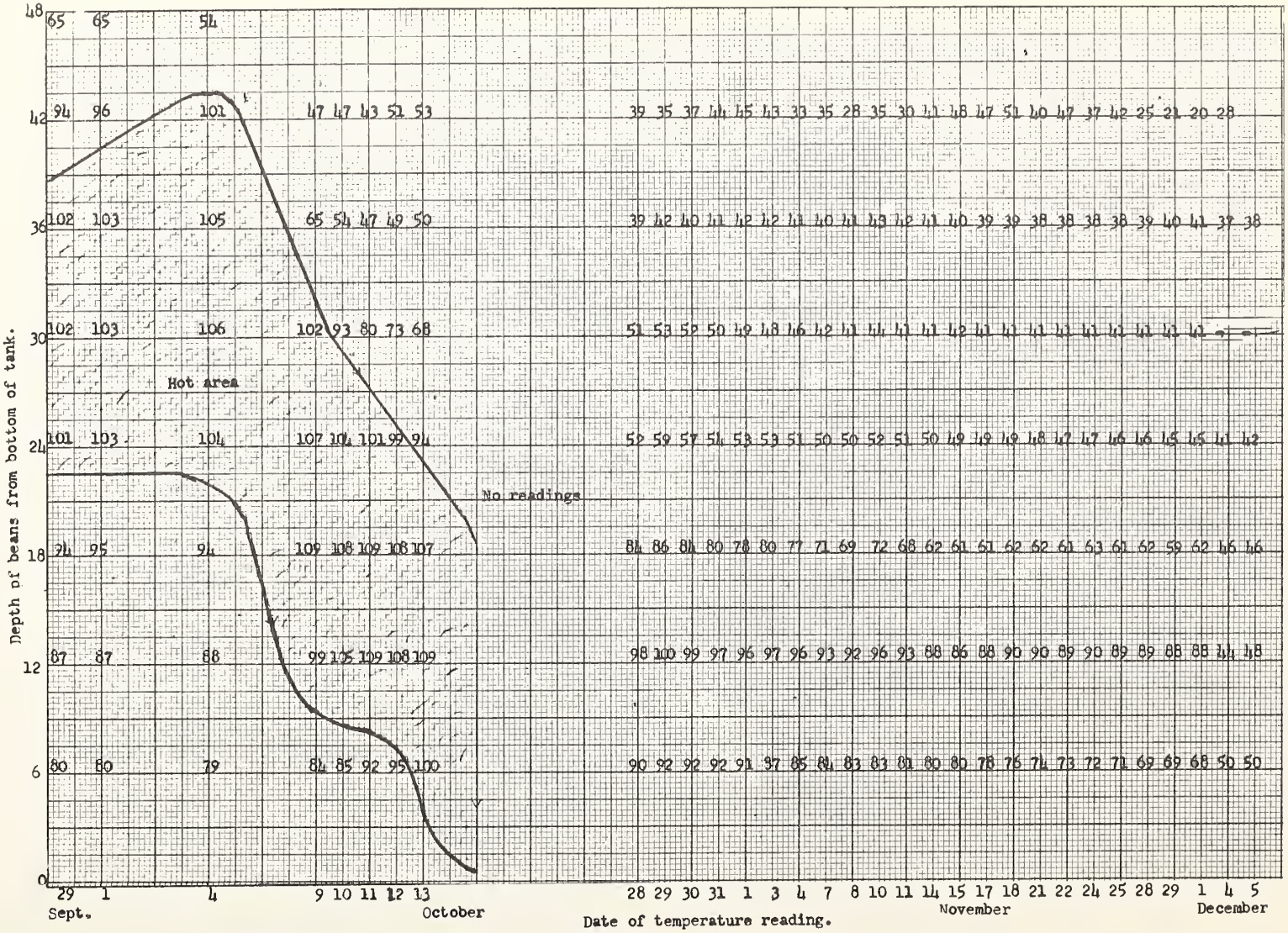
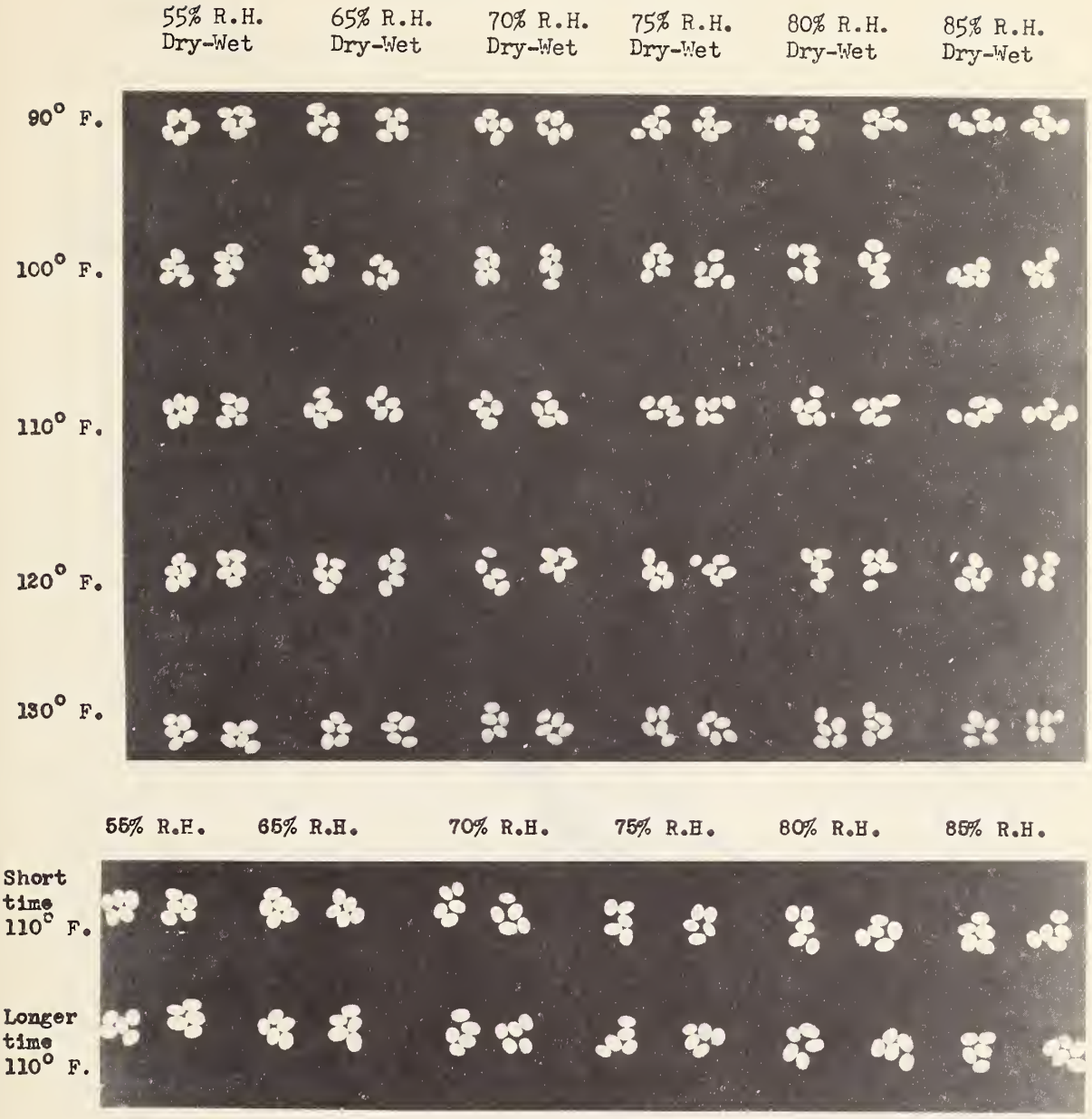


Figure 52.--Bin C. Indicating movement of hot spot during ventilation with outside air exhausted from bottom of tank - September-December 1953.

DISCOLORATION OF WHILE PEA BEANS AT VARYING TEMPERATURES AND PERCENT RELATIVE HUMIDITY



Two lots of beans, "dry" (14%) and "wet" (20%) were stored at the temperatures and relative humidities shown until they reached constant weight. Note the very much discolored beans at the higher relative humidities and temperatures - especially 120° and 130°F.

When the beans at 110° were stored for a longer time, note that the discoloration increased.

Figure 53.--Discoloration of pea beans at varying temperatures and percent relative humidity.

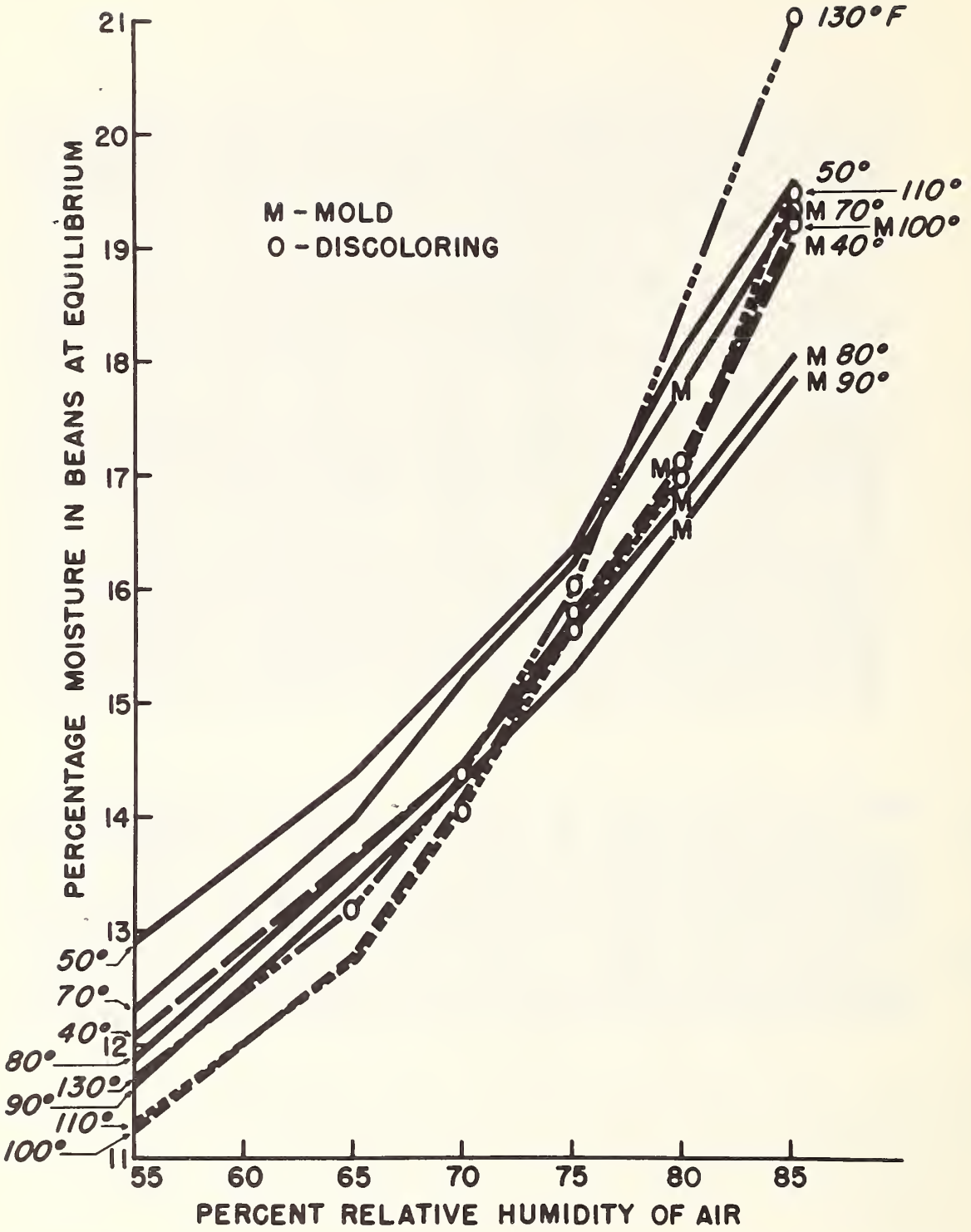


Figure 54 The average moisture contents at each relative humidity and temperature are shown in the curves to show the change in moisture content as the relative humidity changed at various fixed temperatures.

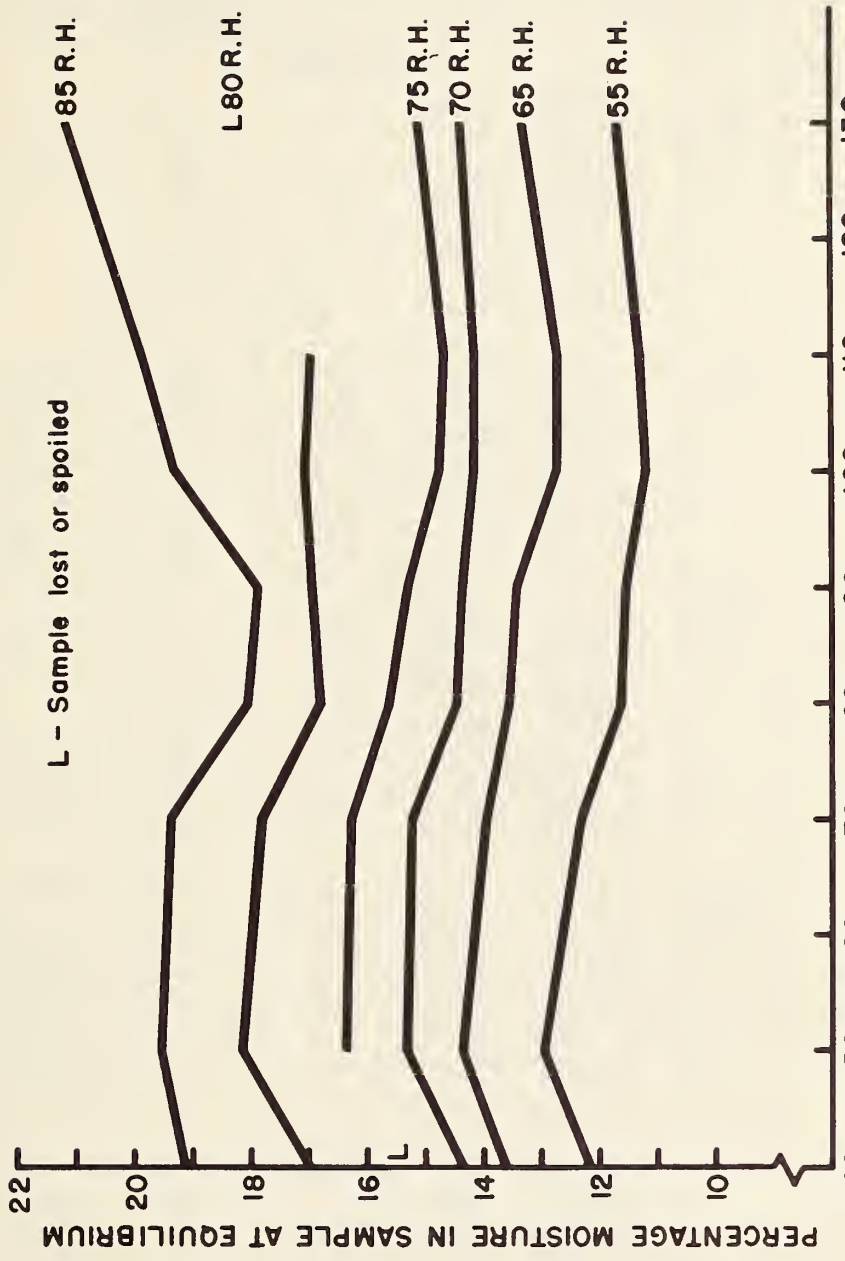


Figure 55 The average moisture contents at each relative humidity and temperature are shown in the curves to show the change in moisture content as the temperatures changed at various fixed relative humidities.

Table 4.--Laboratory studies - Analyses of stored samples - Michigan State University

Storage conditions		Sample origin	Date of sampling	Sample number	Moisture wet basis	Fat acidity	Mold count
Temp.	R. H.						
Degrees F.	Percent				Percent		
85	52	1952	5- 1-53	62-L	8.7	13	20
			5-27-53	74-L	9.5	13	-
			7- 1-53	109-L	10.6	14	400
			8- 2-53	137-L	10.3	18	195
			9- 4-53	187-L	9.7	13	0
			10- 5-53	209-L	10.0	12	8
			1- 1-54	239-S	9.3	12	0
		1951	5- 1-53	60-C	13.9	17	21,428
			5-27-53	75-L	11.7	17	1,180
			7- 1-53	110-L	11.4	16	404
			8- 2-53	138-L	11.3	20	210
			9- 4-53	188-L	10.8	15	236
			10- 5-53	210-L	10.4	12	150
			1- 1-54	240-S	9.6	16	156
85	75	1952	3- 2-53	20-L	12.9	16	36
			3-31-53	27-L	14.8	25	34
			4-28-53	49-L	15.3	21	2
			5-27-53	72-L	15.4	24	0
			7- 1-53	107-L	15.7	31	1,240
			8- 2-53	135-L	17.0	42	1,962
			9- 4-53	186-L	16.5	40	8,320
			10- 5-53	208-L	15.6	44	8
							Discard
		1951	3- 2-53	38-C	17.4	22	200
			3-31-53	28-L	15.8	31	175,000
			4-28-53	50-L	16.6	35	17,530
			5-27-53	73-L	16.4	35	45,333
			7- 1-53	108-L	16.7	39	57,400
			8- 2-53	136-L	18.1	52	132,400
							Discard
85	90	1952	3- 2-53	20-L	12.9	16	36
			3-31-53	29-L	14.1	25	26
			4-28-53	51-L	16.5	20	1,623
			5-27-53	70-L	17.6	32	36,315
			7- 1-53	105-L	20.3	42	378,600
			8- 2-53	133-L	20.1	54	774,000
							Discard
85	90	1951	3- 2-53	38-C	17.4	22	200
			3-31-53	30-L	16.5	30	27,666
			4-28-53	52-L	18.6	38	620,000
			5-27-53	71-L	18.9	40	84,333
			7- 1-53	106-L	21.2	47	1,370,000
			8- 2-53	134-L	19.4	60	5,920,000
							Discard

Table 4 - continued

Storage conditions		Sample origin	Date of sampling	Sample number	Moisture wet basis	Fat acidity	Mold count
Temp.	R. H.						
Degrees F.	Percent				Percent		
60	52	1952	5- 1-53	62-L	8.7	13	20
			5-27-53	80-L	10.0	12	-
			7- 2-53	115-L	11.3	17	70
			7-31-53	143-L	11.4	13	215
			9- 4-53	191-L	11.3	13	8
			10- 5-53	211-L	11.9	11	0
			1- 1-54	235-S	10.6	11	319
		1951	5- 1-53	60-C	13.9	17	21,428
			5-27-53	81-L	13.7	18	-
			7- 2-53	116-L	13.4	18	2,930
			7-31-53	144-L	12.8	16	1,500
			9- 4-53	192-L	12.3	18	1,013
			10- 5-53	212-L	12.2	12	366
			1- 1-54	236-S	10.9	12	782
60	75	1952	3- 2-53	20-L	12.9	16	36
			3-31-53	33-L	14.7	23	4
			4-29-53	55-L	14.9	19	0
			5-27-53	78-L	16.2	22	0
			7- 2-53	113-L	15.9	21	292
			7-31-53	141-L	16.8	19	600
			9- 4-53	189-L	16.7	15	749
			10- 5-53	213-L	12.3	16	28
			1- 1-54	234-S	15.7	19	8
		1951	3- 2-53	38-C	17.4	22	200
			3-31-53	34-L	16.3	26	23,200
			4-29-53	56-L	26.2	28	-
			5-27-53	79-L	18.2	25	55,400
			7- 2-53	114-L	18.8	30	29,300
			7-31-53	142-L	18.2	24	226,600
			9- 4-53	190-L	18.9	24	297,730
							Discard
60	90	1952	3- 2-53	20-L	12.9	16	36
			3-31-53	31-L	16.1	25	0
			4-28-53	53-L	17.9	24	2,740
			5-27-53	76-L	19.1	22	1,720
			7- 2-53	111-L	22.6	21	28,530
			7-31-53	139-L	22.6	32	468,000
							Discard
		1951	3- 2-53	38-C	17.4	22	200
			3-31-53	32-L	17.4	28	54,000
			4-28-53	54-L	24.2	30	18,866
			5-27-53	77-L	23.3	29	44,255

continued

Table 4.--continued

Storage conditions		Sample origin	Date of sampling	Sample number	Moisture wet basis	Fat acidity	Mold count
Temp.	R. H.						
Degrees F.	Percent				Percent		
60	90	1951	7- 2-53	112-L	24.6	32	1,746,000
			7-31-53	140-L	25.3	32	14,720,000
							Discard
40	52	1952	5- 1-53	62-L	8.7	13	20
			5-27-53	84-L	9.5	12	-
			7- 2-53	119-L	10.6	15	0
			7-31-53	137-L	10.8	12	16
			9- 5-53	194-L	10.6	13	34
			10- 5-53	214-L	10.2	10	0
			1- 1-54	237-S	10.3	10	4
		1951	5- 1-53	60-C	13.9	17	21,428
			5-27-53	85-L	14.0	17	-
			7- 2-53	120-L	14.0	18	1,800
			7-31-53	148-L	13.6	15	4,066
			9- 5-53	195-L	13.7	12	300
			10- 5-53	215-L	12.7	11	2,826
			1- 1-54	238-S	12.3	14	1,776
40	90		3- 2-53	20-L	12.9	16	36
			3-31-53	35-L	15.1	26	0
			4-28-53	57-L	16.7	20	0
			5-27-53	82-L	16.6	20	-
			7- 1-53	117-L	18.5	19	0
			7-13-53	145-L	19.5	17	6
			9- 5-53	193-L	19.3	14	28
							Discard
40	90	1951	3- 2-53	38-C	17.4	22	200
			3-31-53	36-L	18.0	26	15,930
			4-28-53	58-L	20.9	25	22,000
			5-27-53	83-L	21.3	22	-
			7- 1-53	118-L	22.3	26	11,930
			7-31-53	146-L	23.0	22	626,800
							Discard
100	52	1952	5- 1-53	62-L	8.7	13	20
			5-27-53	86-L	8.9	12	-
			7- 1-53	121-L	9.2	14	96
			7-31-53	149-L	9.3	11	8
			9- 4-53	184-L	8.8	12	4
			10- 5-53	206-L	9.5	10	0
			1- 1-54	232-S	8.2	11	0

continued

Table 4.--continued

Storage conditions		Sample origin	Date of sampling	Sample number	Moisture wet basis	Fat acidity	Mold count
Temp.	R. H.						
Degrees F.	Percent				Percent		
100	52	1951	5- 1-53	60-C	13.6	17	21,428
			5-27-53	87-C	9.8	14	-
			7- 1-53	122-L	9.4	17	200
			7-31-53	150-L	9.6	15	225
			9- 4-53	185-L	9.7	17	82
			10- 5-53	207-L	8.9	13	40
			1- 1-54	233-S	8.0	18	225
40 (walk-in cooler)	80-85 (variable, with air movement)	1952 Lot A	2- 4-53	11-C	20.5	26	7,820
			2-24-53	19-C	20.3	24	510,000
			3-31-53	37-C	20.5	28	640,000
			4-29-53	59-C	20.6	27	281,000
			5-27-53	88-C	21.5	25	-
			7- 2-53	123-L	22.0	27	297,000
			7-31-53	151-L	21.6	21	1,076,000
			9- 5-53	198-L	22.5	18	3,004,000
							Discard
0 degrees F (walk-in freezer)	(variable, with air movement)	1952 Lot A	3-31-53	39-C	19.1	23	236,000
			4-29-53	61-C	20.1	24	430,000
			5-28-53	90-C	19.8	24	-
			7- 2-53	125-C	18.5	22	268,000
			7-31-53	153-L	17.9	18	816,000
			9- 5-53	197-L	17.9	16	1,111,866
			10- 5-53	216-L	16.9	15	328,000
0 (walk-in freezer)	(variable, with air movement)	1951 Crop	2-17-53	12-C	19.5	25	-
			3-31-53	38-C	17.4	22	112
			4-29-53	60-C	13.9	17	21,428
			5-28-53	89-C	17.4	22	-
			7- 2-53	124-L	17.0	22	2,390
			7-31-53	152-L	17.3	18	5,160
			9- 5-53	196-L	16.0	14	148
			10- 5-53	217-L	13.1	13	262
							Discard

Table 5.--Warehouse studies - Sample Analyses - Michigan State University

Sample origin	Date of sampling	Sample number	Moisture percent	Fat acidity	Mold count
Warehouse D					
Bay City	1- 5-53	2-S	14.04	-	6,200
Bldg. 15	1-29-53	6-S	14.9	32	12,760
Lot 38	2-23-53	5-S	15.8	37	-
	3-30-53	23-S	15.9	39	1,460,000
	4-28-53	44-S	16.1	39	113,000
	5-26-53	66-S	15.7	44	132,000
	6-30-53	102-S	15.0	36	660,000
	7-28-53	129-S	14.9	43	56,000
	9- 1-53	167-S	13.7	29	21,240
	9-28-53	203-S	13.7	30	1,088,800
	11- 4-53	218-S	13.8	32	208,066
	12- 7-53	229-S	14.2	32	99,260
Warehouse D					
Bay City	1- 5-53	3-S	15.6	-	0
Bldg. 15	1-29-53	7-S	15.2	15	2
Lot 66	2-23-53	16-S	15.1	19	0
	3-30-53	24-S	15.0	25	11
	4-28-53	45-S	14.9	21	-
	5-26-53	67-S	14.6	21	2
	6-30-53	103-S	14.0	17	296
	7-28-53	103-S	13.8	23	50
	9- 1-53	168-S	13.7	19	8
	9-28-53	204-S	13.1	13	130
	11- 4-53	219-S	13.6	14	80
	12- 7-53	228-S	14.8	15	110
Warehouse F					
Bay City	1- 5-53	1-S	14.6	-	0
Bldg. 23	1-29-53	5-S	14.0	20	0
Lot 17	2-23-53	14-S	14.3	21	14
	3-30-53	22-S	13.9	25	202
	4-28-53	43-S	14.7	24	7,473
	5-26-53	68-S	13.7	23	8,173
	6-30-53	101-S	13.0	21	1,175
	7-28-53	131-S	13.5	25	436
	9- 1-53	169-S	14.1	30	11,386
	9-28-53	202-S	12.8	24	5,232
	11- 4-53	220-S	13.6	28	29,690
	12- 7-53	230-S	14.2	27	529
Warehouse A					
Bradleyville	4- 7-53	41-S	16.3	22	74
	4-28-53	46-S	15.8	18	15
	5-26-53	69-S	15.1	21	2

continued

Table 5.--Warehouse studies - Sample Analyses - Michigan State University - continued

Sample origin	Date of sampling	Sample number	Moisture percent	Fat acidity	Mold count
Warehouse A Bradleyville	6-30-53	104-S	15.2	17	548
	7-28-53	132-S	13.4	19	136
	9- 1-53	166-S	12.7	18	156
	9-28-53	205-S	12.3	13	48
	11- 4-53	221-S	12.5	12	72
	12- 7-53	231-S	14.6	16	108
Warehouse C Ithaca	1-29-53	10-S	15.6	15	0
	2-23-53	18-S	15.4	17	4
	3-30-53	26-S	14.8	27	6
	4-28-53	48-S	15.5	20	8
	5-26-53	63-S	15.0	21	22
	6-30-53	98-S	14.8	18	366
	7-28-53	126-S	13.3	19	128
	9- 1-53	171-S	11.9	15	180
	9-28-53	199-S	11.7	10	60
	11- 4-53	222-S	12.8	12	232
	12- 7-53	225-S	14.1	13	50
Warehouse B Breckenridge	1-29-53	9-S	14.6	14	11
	2-23-53	17-S	14.2	16	91
	3-30-53	25-S	14.3	25	142
	4-28-53	47-S	15.5	20	0
	5-26-53	64-S	14.7	22	0
	6-30-53	99-S	14.1	17	12
	7-28-53	127-S	12.7	21	62
	9- 1-53	170-S	11.9	15	64
	9-28-53	200-S	11.7	12	36
	11- 4-53	223-S	12.7	14	60
	12- 7-53	226-S	13.7	15	58
Warehouse E Carrollton	1-29-53	8-S	14.1	18	0
	2-23-53	13-S	13.3	20	18
	3-30-53	21-S	14.4	26	0
	4-28-53	42-S	15.4	27	60
	5-26-53	65-S	15.1	25	2
	6-30-53	100-S	13.9	18	24
	7-28-53	128-S	14.4	30	1,017
	9- 1-53	172-S	13.3	24	11,880
	9-28-53	201-S	13.8	19	192
	11- 4-53	224-S	13.9	21	370
	12- 7-53	227-S	14.6	23	457

Table 6.--Weather data and fan operation by weeks, Ash Grove, Indiana

Year and week beginning	Temperature			Relative humidity			Fan operation
	Outdoor	Indoor		Outdoor	Indoor		
		Without fan operation	With fan operation		With fan	Without fan	
	°F.	°F.	°F.	Percent	Percent	Percent	Hours
1953							
Feb. 23	-	39.8	-	-	69.4	-	0
Mar. 2	-	34.2	30.2	-	81.0	86.0	17
9	46.5	46.4	43.7	-	79.0	81.2	9
16	50.4	51.5	49.0	-	75.1	80.9	22.5
23	52.5	42.3	42.9	-	75.7	83.9	17
30	42.0	44.7	41.6	86.1	84.7	83.2	10
Apr. 6	45.7	48.1	43.7	81.1	76.3	82.8	14
13	37.6	40.5	43.5	81.0	79.5	81.6	15.5
20	51.3	51.8	48.1	73.6	71.3	81.6	16
27	53.8	55.0	53.9	80.0	77.9	78.8	12
May 4	59.6	61.7	58.0	78.4	74.4	81.1	21
11	57.0	59.3	63.0	87.6	84.9	88.0	5
18	60.2	63.3	62.4	83.3	79.9	84.0	8
25	68.9	71.1	-	74.3	68.3	-	0
June 1	67.5	71.4	-	76.9	69.4	-	0
8	70.0	74.3	68.3	84.5	78.3	86.0	10
15	75.1	78.1	74.6	75.0	71.3	86.4	26
22	75.6	80.2	75.2	76.4	71.9	81.7	14
29	76.0	81.1	77.8	81.0	76.7	85.6	11
July 6	69.5	73.4	73.2	78.6	75.4	81.2	9
13	74.7	79.5	76.9	80.7	72.8	81.4	14
20	72.4	78.9	76.5	82.0	77.3	79.9	15
27	78.7	83.8	79.0	83.0	77.3	84.2	19
Aug. 3	70.0	76.6	72.2	85.0	81.0	92.3	7
10	68.6	75.3	75.5	78.9	76.6	77.9	3
17	65.0	72.4	73.4	72.5	72.4	76.6	13
24	74.6	79.4	75.3	70.4	67.6	78.0	7
31	71.3	77.2	76.0	73.3	69.0	82.5	4.5
Sept. 7	61.6	67.2	67.0	71.0	70.8	81.7	6.5
14	61.6	65.5	65.8	71.5	74.0	76.3	8
21	57.9	64.1	75.6	70.9	70.6	55.9	25
28	63.9	67.6	69.5	66.4	65.9	69.8	27
Oct. 5	48.8	57.7	70.2	76.6	74.3	59.2	33
12	-	60.1	74.2	-	69.3	55.1	31.5
19	56.6	62.1	71.9	67.8	63.1	53.4	34
26	46.5	52.4	61.5	75.2	77.7	59.6	24

continued

Table 6.--Weather data and fan operation by weeks, Ash Grove, Indiana - continued

Year and week beginning	Temperature			Relative humidity			Fan operation
	Outdoor	Indoor		Outdoor	Indoor		
		Without fan operation	With fan operation		With fan	Without fan	
	°F	°F	°F	Percent	Percent	Percent	Hours
1953							
Nov. 2	37.1	44.5	54.1	63.8	63.2	52.7	34
9	42.5	46.0	53.2	66.7	65.8	60.5	33
16	48.7	51.6	60.7	70.5	50.3	54.4	23
23	-	39.0	39.8	-	82.1	81.8	7.5
30	-	41.9	45.3	-	80.7	69.9	22
Dec. 1	-	39.8	44.8	-	72.3	58.3	28
14	-	-	-		-	-	-
21		-	-		-	-	-
28		-	-		-	-	24
1954							
Jan. 4		-	-		-	-	5
11		-	-		-	-	12
18		33.2	28.7		80.0	77.3	10
25		34.8	-		75.9	-	
Feb. 1		-	-		-	-	
8		31.0	-		71.1	-	52
15		38.6	-		75.9	-	
22		31.2	-		77.1	-	
Mar. 1		23.9	-		71.9	-	
8		31.6	39.3		61.3	67.8	15
15		30.1	35.3		69.6	61.0	14
22		36.1	33.5		72.5	65.5	6
29		40.3	-		67.1	-	-
Apr. 5		53.1	49.6		71.1	73.3	14
12		55.4	56.3		68.0	70.8	14
19		60.7	61.7		69.1	71.0	12
26		-	-		-	-	8
May 3		46.6	45.0		65.9	72.3	8
10		56.4	54.9		-	-	11
17		59.3	56.9		-	-	19
24		-	-		-	-	-
31		62.8	-		71.2	-	-

Table 7.--Fat acidity value of samples from beans stored at Ash Grove, Indiana

Sample code 1/	Initial	1953								1954			
		Mar. 19	Apr. 23	May 21	June 26	July 28	Sept. 2	Oct. 9	Nov. 27	Jan. 11	Mar. 15	Apr. 26	June 3
	Number	Number	Number	Number	Number	Number	Number	Number	Number	Number	Number	Number	Number
1-AR	19	14	13	11	16	17	N. S.	19	28	22	24	23	28
1-BR	20	17	12	11	18	21	2/	23	34	27	28	28	20
1-CR	19	20	16	14	20	21		26	34	28	27	31	32
1-T		20	18	14	19	21		30	37	31	29	32	36
2-AR	22	20	19	17	23	25		38	40	35	33	36	43
2-BR	24	22	17	16	22	25		38	38	36	32	34	37
2-CR	24	20	17	16	21	24		35	37	33	31	33	37
2-T		20	20	17	22	25		30	34	31	30	36	38
3-A	17	19	16	14	18	21		30	30	25	25	32	31
3-AR		17	14	13	18	18		25	30	26	19	27	30
3-B	19	19	17	14	17	17		26	28	25	18	29	28
3-BR		17	10	10	16	16		20	25	20	22	26	24
3-C	18	14	13	12	15	18		28	27	25	22	29	29
3-CR		18	15	13	17	18		24	31	26	22	29	34
3-DSH	17	16	13	14	15	19		28	32	26	26	24	35
3-DRSH		15	12	11	15	17		24	32	28	26	30	34
3-DL		16	16	12	15	17		27	30	28	23	32	35
3-DRL		14	11	13	16	17		21	31	27	24	35	33
3-E	19	16	14	12	15	16		27	31	23	25	27	31
4-SH	21	20	17	17	22	25		40	39	31	29	34	36
4-L	22	18	16	18	19	21		28	29	25	22	24	34
5-SH	20	17	15	16	16	21		26	30	16	23	19	33
5-L	21	20	15	16	20	21		27	32	29	25	28	32
6-SH	17	17	12	14	17	20		24	31	26	24	28	31
6-L	19	18	14	13	17	20		25	31	26	26	34	34
7-M	22	18	14	15	19	22		27	30	27	24	30	28
7-N		21	16	21	20	21		25	31	26	25	29	30

1/ See sample treatment in table 2.
2/ Not sampled.

Table 8.--Moisture content of samples taken in beans stored at Ash Grove, Indiana 1/

Sample code 2/	Initial	1953								1954			
		Mar. 19	Apr. 23	May 21	June 26	July 28	Sept. 2	Oct. 9	Nov. 27	Jan. 11	Mar. 15	Apr. 26	June 3
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
1-AR	14.5	14.8	15.0	15.0	15.3	15.3	N. S.	13.8	13.6	13.3	13.3	14.0	14.0
1-ER	15.7	15.8	15.4	15.8	16.2	16.3	3/	15.3	15.5	14.4	14.4	14.8	14.8
1-CR	14.8	15.4	15.3	15.5	15.8	15.7		14.4	14.3	14.2	14.1	14.1	14.2
1-T		15.6	15.2	15.7	15.1	14.9		13.9	14.2	13.7	14.4	14.5	14.5
2-AR	15.3	16.1	15.7	15.9	16.3	16.3		15.1	14.8	14.0	14.1	14.5	14.9
2-ER	15.9	16.5	15.9	16.0	16.2	16.1		14.6	14.3	13.6	14.3	14.6	14.6
2-CR	15.9	15.8	15.5	15.8	15.9	16.0		14.4	14.4	13.8	13.8	14.0	14.2
2-T		16.2	15.5	15.7	14.6	14.1		12.4	12.8	12.9	13.2	13.3	13.0
3-A	14.7	14.9	14.6	14.8	14.7	14.3		12.8	13.0	12.9	13.3	13.4	13.3
3-AR		14.4	14.3	14.4	14.9	14.7		13.1	13.2	13.3	13.3	13.5	13.7
3-E	15.2	15.5	14.9	14.8	14.2	14.0		11.9	12.2	12.9	12.6	12.9	13.1
3-ER		15.1	14.7	14.9	15.0	15.0		12.9	13.3	13.4	13.6	13.8	13.8
3-C	14.8	15.4	14.9	15.0	14.3	14.0		12.3	12.4	12.7	13.2	14.1	13.0
3-CR		15.2	14.7	15.0	14.8	14.9		13.2	13.7	12.3	13.4	13.3	14.1
3-DSH	14.6	15.3	14.8	14.9	14.4	14.1		12.6	13.0	12.6	13.7	13.6	13.7
3-DRSH		14.9	14.4	14.8	15.1	15.6		14.4	13.8	13.3	13.7	14.1	14.2
3-DL		14.7	14.2	14.0	12.7	13.0		11.6	12.5	12.7	13.0	13.4	13.1
3-DRL		15.6	14.8	14.8	15.3	15.4		14.3	13.8	12.9	13.6	13.6	14.1
3-E	14.6	15.0	14.6	14.9	14.5	14.4		12.9	13.2	12.7	13.3	13.6	13.8
4-SH	15.1	16.1	15.9	16.5	16.5	16.5		15.0	13.1	11.7	11.5	11.7	11.7
4-L	15.4	15.7	15.5	15.8	15.5	14.9		11.9	9.7	9.4	9.8	10.4	10.6
5-SH	15.3	15.7	15.3	15.8	15.7	15.3		11.8	11.2	11.3	11.6	12.1	12.3
5-L	15.4	15.6	15.1	15.6	15.5	15.6		12.0	11.3	11.4	11.5	12.1	12.2
6-SH	14.9	15.2	14.7	15.1	15.2	14.7		13.1	13.6	12.7	13.5	14.0	14.0
6-L	14.8	15.2	15.1	15.5	15.5	15.2		13.5	13.7	11.2	13.6	14.4	14.4
7-M	14.8	15.2	14.7	15.4	15.2	15.3		11.7	10.8	10.3	11.1	11.7	12.0
7-N		15.5	14.7	14.9	15.1	13.2		10.6	10.2	10.0	10.8	11.0	11.2

1/ By wet bulb method
2/ See sample location in table 2.
3/ Not sampled.

Table 9.--Average temperatures of bean stacks located at Ash Grove, Indiana

Sample code	1953																	1954					
	Feb. 19	Mar. 5	Mar. 19	Apr. 2	Apr. 16	Apr. 23	May 7	May 21	June 4	June 26	July 14	July 28	Aug. 11	Sept 2	Sept 18	Oct. 9	Oct. 30	Nov. 27	Jan. 11	Feb. 12	Mar. 15	Mar. 29	Apr. 26	June 3
	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F
1-A	33.0	36.4	40.0	42.6	46.9	44.8	53.3	58.0	64.6	74.5	72.3	75.1	75.4	74.0	65.0	56.3	56.4	48.4	35.3	32.5	34.5	41.0	54.3	59.3
1-B	32.5	35.9	41.5	43.0	46.4	46.0	55.1	59.9	65.9	75.6	72.4	77.3	74.8	75.8	62.6	56.4	54.9	46.4	33.4	32.2	33.8	41.4	55.6	60.1
1-C	32.3	36.3	42.8	43.1	46.3	46.3	56.0	60.1	65.9	75.5	72.0	76.6	74.1	76.9	63.4	56.8	54.8	46.1	34.0	32.4	34.3	42.8	58.1	61.1
2-A	32.3	36.3	41.9	43.6	47.6	44.6	56.0	59.8	66.3	75.6	72.8	77.0	75.3	76.8	63.3	57.8	56.4	47.0	34.4	32.4	34.9	42.6	57.4	61.4
2-B	32.4	36.3	44.5	43.5	47.4	46.4	57.9	63.5	66.0	77.8	73.6	78.6	75.5	79.0	63.1	56.1	54.9	46.4	35.1	33.8	35.9	44.8	61.3	63.6
2-C	32.3	35.6	44.6	43.1	47.0	46.9	57.6	61.8	67.6	76.6	72.8	78.4	74.4	78.8	62.3	55.4	54.5	46.1	33.6	33.0	34.4	44.1	60.5	63.1
3-A	32.0	35.8	43.3	42.9	47.0	44.1	56.3	61.5	67.1	77.1	72.0	77.4	75.0	78.1	61.9	55.9	55.0	46.5	33.4	32.9	35.8	44.5	59.1	63.6
3-B	32.1	35.5	44.6	43.5	46.6	46.4	57.4	62.8	67.4	78.0	73.3	78.5	74.3	80.8	61.9	55.0	53.9	44.5	33.2	32.4	34.6	44.9	62.8	63.8
3-C	32.0	34.5	44.5	43.8	45.9	46.5	57.4	62.5	67.3	77.0	72.0	77.8	72.5	78.9	61.4	51.6	50.9	42.3	32.4	33.4	33.4	44.6	61.3	63.6
3-D	32.5	36.3	41.4	43.1	46.8	45.0	54.3	58.5	64.3	73.3	70.8	74.0	73.1	74.9	62.3	57.5	56.3	49.5	36.9	34.0	36.1	42.5	55.8	58.9
3-E	32.4	35.6	43.3	43.3	46.9	46.8	56.6	62.1	66.1	76.4	72.1	77.3	72.5	77.1	61.9	56.1	55.9	45.9	33.9	32.6	34.5	44.1	60.6	62.9
4	34.5	35.2	42.8	45.2	46.5	46.6	59.1	63.1	65.7	78.0	77.0	79.7	78.8	80.2	65.8	67.5	63.5	49.8	39.5	44.8	44.7	45.8	67.0	66.4
5	32.7	36.1	42.6	43.7	45.2	45.5	56.5	60.4	65.0	76.7	73.4	77.3	76.1	78.6	63.4	62.2	58.3	47.8	36.4	39.3	41.5	44.2	60.7	63.6
6	32.4	36.8	42.3	43.3	47.3	45.3	55.6	57.4	65.6	75.9	72.9	76.5	74.9	76.9	62.6	57.8	56.8	46.0	34.6	34.2	37.8	44.2	57.5	61.3
7	32.1	36.2	43.8	44.2	47.1	46.5	57.1	61.0	64.8	76.5	74.1	77.4	74.9	78.0	63.0	60.8	59.5	47.0	36.3	39.6	41.9	45.6	62.6	63.6

Table 10.--Inspection analysis of pea beans stored at Ash Grove, Indiana

Date and number	Moisture	Damage	Foreign material	Splits	Cracked seed-coats	Condition	Federal grade
	Percent	Percent	Percent	Percent	Percent		
March 1953							
1	16.0	2.5	-	0.4	1.0	Musty	U.S. Sample
2	16.5	2.0	0.3	-	1.3	do	do
3	15.5	2.7	0.1	0.2	0.9	do	do
4	16.0	2.4	0.05	0.2	1.9	do	do
5	16.0	3.1	0.1	1.2	5.0	do	do
6	15.5	1.1	0.1	0.2	1.3	-	U.S. No. 1
7	16.0	2.9	0.1	0.2	2.3	Musty	U.S. Sample
February 1954							
1	15.2	1.5	0.1	0.6	4.7	Musty	Sample
2	16.1	2.8	0.3	0.4	3.0	do	do
3	14.7	2.5	0.2	0.3	1.5	-	No. 2
4	12.4	2.2	0.04	-	2.3	Musty	Sample
5	12.5	1.4	0.03	1.0	6.5	do	do
6	14.5	2.4	0.1	0.3	-	-	No. 2
7	11.6	2.4	0.1	0.2	1.4	Musty	Sample
June 1954							
1	16.0	2.2	-	0.6	3.7	Musty	Sample
2	15.0	3.4	0.2	0.1	1.0	do	do
3	15.0	1.9	0.1	0.5	0.7	-	No. 2
4	12.5	2.5	0.1	0.2	1.6	Musty	Sample
5	13.5	1.5	-	0.5	8.0	do	do
6	16.0	2.3	0.2	0.4	1.5	do	do
7	13.0	2.1	0.1	0.3	3.0	do	do

Table 11.--Moisture content and fat acidity of beans stored, by samples, Caro, Michigan specified dates 1953 and 1954

Sample identification 1/	Moisture content					Fat acidity				
	1953			1954		1953			1954	
	July 21	August 13	October 18	March 2	June 7	July 21	August 13	October 18	March 2	June 7
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
3 Inner top	16.1	14.0	11.5	14.9		23	22	N. S.	35	
3 Inner bottom	16.5	14.9	12.1	14.3		23	22	2/	27	
3 Outer top	15.1	14.0	12.2	14.9		19	23		34	
3 Outer bottom	13.6	14.9	14.4	14.2		12	19		32	
5 Inner top	14.2	12.0	13.6	14.1	14.0	18	20		21	34
5 Inner bottom	15.0	12.0	14.0	12.6	12.4	16	13		24	30
5 Outer top	14.1	14.7	13.4	13.3	12.8	17	23		32	32
5 Outer bottom	14.9	15.8	13.7	14.0	13.6	14	17		29	33
6 Inner	15.7	14.5	13.5	14.4	13.9	24	21		22	25
6 Outer	15.2	15.1	13.8	15.0	14.5	18	15		21	26
9 Inner	14.8	15.9	14.3	14.8	14.7	14	18		26	31
9 Outer	14.5	15.3	13.7	14.6	14.3	15	19		25	33

1/ Sample key (last digit of bin number).

Bin 98613 Bulk beans 1/2 HP motor and 20" fan draw air through beans

Bin 98615 Bulk beans 1/20 HP motor & 8" fan vertical dust in center of bins

Bin 98616 Bags edged - square chimney

Bin 98619 Bags flat - square chimney

3 Inner top and bottom
3 Outer top and bottom

5 Inner top and bottom
5 Outer top and bottom

6 Inner - sample from inside chimney
6 Outer - sample from outer edge of stack

9 Inner - sample from inside chimney
9 Outer - sample from outer edge of stack

Samples marked inner top and inner bottom from center of bin.

Top is surface sample. Outer top and bottom from outer 1' of bin.

2/ Not sampled for fat acidity.

Table 12.--Temperature at specified locations in silo by thermocouple positions at selected intervals, beginning September 1953 1/

Date	Time	Thermo-couple identifi-cation	Temperature in bin B-2 at thermocouple position								
			1	2	3	4	5	6	7	8	9&10
1953			°F	°F	°F	°F	°F	°F	°F	°F	°F
Sept.29	8:00 A.M.	1	88.0	92.0	84.5	77.0	88.0	90.0	64.2	64.2	64.2
	do	1 A	-	89.2	67.5	83.8	71.8	91.0	91.0	78.2	64.2
Oct. 1	do	1	90.3	93.0	85.0	77.0	88.5	91.8	63.8	63.8	63.8
	do	1 A	-	90.0	66.5	83.5	72.5	91.5	92.0	80.2	63.5
Oct. 4	7:30 A.M.	1	84.0	97.0	87.5	78.2	88.6	94.5	58.5	52.0	52.0
	do	1 A	-	-	56.0	86.5	73.7	91.5	94.5	87.0	52.2
Oct. 9	8:00 A.M.	1	98.0	88.2	80.0	91.5	97.0	59.2	46.5	46.5	46.5
	do	1 A	87.5	67.5	56.0	76.0	94.5	96.8	87.5	67.5	46.2
Oct.10	10:30 A.M.	1	94.0	85.2	83.0	95.0	96.0	50.5	46.0	46.0	46.0
	do	1 A	82.0	65.5	77.5	55.5	96.0	96.0	82.2	63.5	46.0
Oct.11	8:00 A.M.	1	89.5	83.0	93.2	98.0	92.2	47.7	42.5	42.5	42.5
	do	1 A	74.5	74.5	77.0	96.0	97.5	92.0	75.0	48.0	42.5
Oct.12	do	1	87.5	83.5	97.5	98.2	87.5	48.0	50.0	50.0	50.0
	do	1 A	71.0	71.0	56.0	98.0	97.8	89.5	71.0	58.5	50.5
Oct.13	do	1	88.0	89.5	101.0	99.2	83.8	49.5	53.0	53.0	53.0
	do	1 A	67.2	58.0	57.5	58.5	97.5	88.0	87.5	52.2	52.2
Oct.28	12:30 P.M.	1	93.7	102.6	96.2	76.5	52.2	41.7	39.5	39.5	39.5
	do	1 A	45.8	45.0	46.2	90.0	62.0	50.7	46.0	39.5	39.5
Oct.29	8:00 A.M.	1	95.5	104.5	99.5	79.5	55.0	44.2	35.0	35.0	35.0
	do	1 A	53.0	-	40.5	100.0	93.5	64.5	53.2	45.6	35.0
Oct.30	do	1	95.0	104.0	98.5	78.5	54.0	43.0	36.5	36.5	36.5
	do	1 A	52.0	-	90.0	99.0	92.5	62.2	51.5	45.2	40.5
Oct.31	do	1	94.5	102.0	96.5	76.0	52.7	41.5	48.7	48.5	48.5
	do	1 A	50.0	-	97.0	90.0	54.0	50.0	48.5	48.5	48.5
Nov. 1	do	1	94.2	102.0	96.0	75.2	52.2	41.0	44.8	44.8	44.8
	do	1 A	49.0	-	89.0	98.5	90.0	58.0	49.0	42.5	44.5

1/ There is a 6-foot interval between each position on the thermocouple and the 1 A string is staggered 3 feet lower in the silo to give temperature at each 3 feet of beans.

Table 13.--Moisture and fat acidity in bulk dry beans stored in two silo tanks, Marysville, Michigan, bimonthly beginning August 1953

Moisture

Identification	Aug.13	Aug.29	Sept.12	Sept.26	Oct.10	Oct.24	Nov.7	Nov.21	Dec.5
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
Silo B-2									
Surface	15.7	16.5	17.2	15.6	14.5	15.0	13.9	15.2	15.2
4 feet	16.1	15.9	15.3	15.9	14.8	15.4	14.5	15.5	15.1
7 feet	16.1	16.4	16.1	15.4	14.4	15.3	15.2	15.7	15.2
Bottom	16.6	16.1	16.2	14.8	13.9	11.6	15.0	14.7	14.5
Average	16.1	16.2	16.3	15.4	14.4	14.3	14.6	15.3	15.0
C-3									
Surface	16.1	17.2	17.8	15.8	15.3	14.8	13.9	14.6	13.8
4 feet	16.2	16.6	16.7	15.5	15.7	15.2	15.7	16.1	15.8
7 feet	15.8	16.6	16.6	15.7	15.5	15.3	15.9	15.9	15.6
Bottom	15.6	15.5	15.3	15.1	12.4	11.3	13.6	14.3	11.4
Average	15.9	16.5	16.6	15.5	14.7	14.2	14.8	15.2	14.2

Fat acidity

Identification	No.	No.	No.	No.	No.	No.	No.	No.	No.
Silo B-2									
Surface	22	24	30	28	31	22	31	34	29
4 feet	22	21	29	31	29	24	33	22	28
7 feet	22	25	30	26	31	27	24	38	30
Bottom	20	21	26	25	25	19	34	36	22
Average	22	24	29	27½	29	23	30	35	27
C-3									
Surface	21	26	36	31	31	26	29	37	32
4 feet	22	24	31	33	30	26	33	38	33
7 feet	21	23	33	29	28	24	35	38	34
Bottom	20	17	30	29	27	22	34	38	26
Average	21	23	32½	30½	29	24½	33	38	31

Table 14.--A sample of "wet" and a sample of "dry" beans were placed at each of the relative humidities and temperatures shown in the table, and, with occasional weighings, were left until they had attained constant weight. The percentage moisture in these beans was determined by loss in vacuum in 44 hours at 100°F.

Sample R. H. percent	Percentage moisture at equilibrium at the temperature, F°. shown								
	40°	50°	70°	80°	90°	100°	(first) 110°	(second) 110°	130°
55 wet	12.69	12.94	12.21	11.77	11.53	11.25	11.40	11.19	11.71
55 dry	11.49	12.91	12.44	11.87	11.70	11.15	11.40	10.99	11.61
55 average	12.09	12.92	12.32	11.82	11.61	11.20	11.40	11.09	11.66
65 wet	14.08	14.50	13.96	13.56	13.34	12.88	12.57	12.80	12.30*
65 dry	13.11	14.19	14.02	13.64	13.48	12.66	12.54	12.88	13.16*
65 average	13.60	14.34	13.99	13.60	13.41	12.77	12.55	12.84	13.23
70 wet	14.73	15.52	15.27	14.49	14.37	14.27	14.73	13.76	14.42*
70 dry	14.02	15.14	15.21	14.47	14.37	14.10	14.39	13.61	14.26*
70 average	14.38	15.33	15.24	14.48	14.37	14.19	14.56	13.68	14.34
75 wet		16.53	16.28	15.68	15.34	15.76	15.44*	16.01*	15.97**
75 dry	Lost	16.22	16.30	15.56	15.30	15.76	15.57	15.66*	16.11**
75 average		16.37	16.29	15.62	15.32	15.76	15.50	15.83	16.04
80 wet	17.10	18.23	17.98	16.81		17.16*	16.58**	17.40*	
80 dry	16.89	18.03	17.69	16.83	Lost	17.07	16.46*	17.42*	Lost
80 average	17.00	18.13	17.83	16.82		17.11	16.52	17.41	
85 wet	19.08	19.59	19.47	18.06	17.84	19.32*	19.44**	19.48**	20.70**
85 dry	19.16	19.56	19.31	18.02	17.94	19.33*	19.11*	20.17*	21.57**
85 average	19.12	19.57	19.39	18.04	17.89	19.32	19.27	19.82	21.14

* Discolored
** Discolored badly

Table 15.--The duration of exposure at the various temperatures is shown

Sample	Temperature	Start	Finish	Approximate days duration
	First lot of beans			
1	90°F.	Nov. 7, 1952	Dec. 8, 1952	30
2	80°F.	Dec. 12, 1952	Feb. 1, 1953	50
3	70°F.	Feb. 3, 1953	Mar. 20, 1953	45
4	50°F.	Mar. 4, 1953	Aug. 8, 1953	155
5	110°F. (First)	Aug. 19, 1953	Nov. 9, 1953	80
	Second lot of beans			
6	110°F.	Nov. 13, 1953	Dec. 1, 1953	20
7	100°F.	Dec. 4, 1953	Dec. 28, 1953	24
8	130°F.	Jan. 8, 1954	Jan. 20, 1954	12
9	40°F.	Jan. 31, 1954	Apr. 13, 1954	122
10	90°F.	Feb. 25, 1954	Apr. 5, 1954	40

Table 16.--Average mold count per gram of beans stored at different relative humidities and temperatures until constant weight was attained.

Dry beans (at start)

R. H.	40°	50°	70°	80°	90°	100°	110°	110°	130°
	Temperature of storage °F								
55	24	24	14	16	24	948	8	0	0
65	36	0	4	4	36	228	0	0	0
70	6	4	2	2	6	94	36	0	0
75	0	0	11	4	0	0	74,344	12	0
80	2	4	11	11	2	24	0	4	0
85	0	0	34	0	0	284,800	0	0	4

Percent moisture at 80° R. H.

Percent moisture at 85° R. H.

	Wet beans (at start)								
55	20	68	100	14	70	420	4	122	0
65	28	40	164	2	14	232	8	4	0
70	36	28	60	14	58	106	4	32	0
75	4	0	51	0	2	0	0	4	0
80	40	12	17	350	40	4,260	0	0	0
85	8	12	404	97,533	4	3,382,000	0	4	0

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